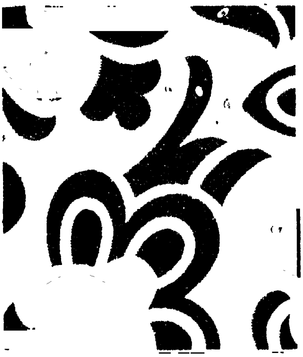
COLOUR-MATCHING ON TEXTILES

FRONTISPIECE

COLOUR MATCHING.

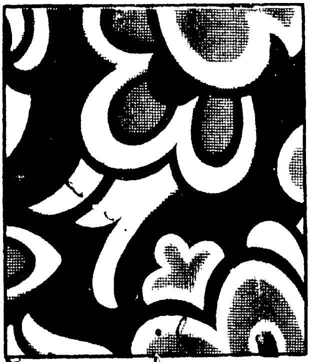
FIG 1.

Daylight Appearance



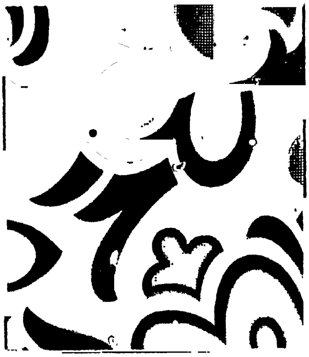
Gaslight Appearance

FIG 3.



Daylight Appearance

FIG 4.



Gaslight Appearance

This Plate illustrates the abnormal modification in some dyed shades under artificial light.

See Chapter IX.

COLOUR-MATCHING

ON

TEXTILES

MANUAL INTENDED FOR THE USE OF
DYERS, CALICO PRINTERS, AND
TEXTILE COLOUR CHEMISTS

CONTAINING
COLOURED FRONTISPIECE, TWENTY-NINE ILLUSTRATIONS,
AND FOURTEEN DYED PATTERNS IN APPENDIX

BY

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PREFACE.

Although a valuable and extensive literature is already devoted to the textile arts, no book has yet appeared on the important subject of the colour-matching of dyed textiles. The subject is a comprehensive one, comprising as it does the study of colour-perception, the qualities of day-light, the optical properties of the fibres and dyestuffs employed, and also the influences of artificial illumination on colour appearances.

This little manual attempts, as far as possible, to systematise and elucidate the many perplexing phenomena that come before the dyer and colour chemist in the course of their everyday work. How far this attempt succeeds lies with the reader himself to judge; but I hope it may prove a genuine help to the practical man as well as to the student.

I have pleasure in expressing my special thanks to my brother, James Paterson, colour chemist, Eskbank, for the assistance he has given me in carefully revising all the proof-sheets, and for many valuable suggestions; and likewise to my esteemed friend, Robert Irvine, F.C.S., F.R.S.E., of Royston, Granton, for his kind interest and advice during the progress of this work.

The dyed patterns illustrating the text I owe to the courtesy of the two eminent colour firms mentioned in the Appendix.

D. F

Leabank,
Rosslyn, Midlothian,
July, 1901.

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COLOUR-MATCHING ON TEXTILES.

CHAPTER I.

INTRODUCTION—LIGHT AND COLOUR A SENSATION—STRUCTURE OF THE EYE—THE RETINA—COLOUR-PERCEPTION—PRIMARY COLOUR SENSATIONS

THE delicate art of colour-matching has ever proved a source of difficulty to the dyer and textile colourist. Even in the earliest annals of industrial history we learn that the skill of the famous dyers of ancient Tyre was often put to the severest test in the matching of their renowned Tyrian purple to that particular amethyst hue which was then so much esteemed.[1]

If the matching of dyed colours was found to be a difficulty *then*, when the daylight was clear and unpolluted by the smoke-cloud of industry, when colours were simple and textile fabrics few, the difficulty is very much increased *now*, when we consider the impure atmosphere of our large industrial cities, the many different kinds of fabrics, and the complexity of the innumerable shades which are demanded by the tastes and fashions of the present day.

Before a good match of any coloured material can be made, either on the palette or on dyed fabric, we must, in the first place, be endowed with eyes capable of distinguishing the finer gradations of hue; and, at the same time, in order to see the colours in their truest aspect, the colours themselves must be illumined with a good white quality of daylight.

At the very threshold, therefore, of our study of colour-matching are two questions of pre-eminent importance, *i.e.*, **Colour-Perception** and **Daylight**; and to these we will first confine our attention.

---

[1] Pliny, lib. ix., chaps. 36-41.

COLOUR-PERCEPTION.

§ 1. **Light and Colour a Sensation.**—In the present scientific age every schoolboy is acquainted with the famous experiment of Newton's, whereby a beam of white light is decomposed, by means of a glass prism, as shown in Fig. 1, into its various constituent colours—red, orange, yellow, green, blue and violet.

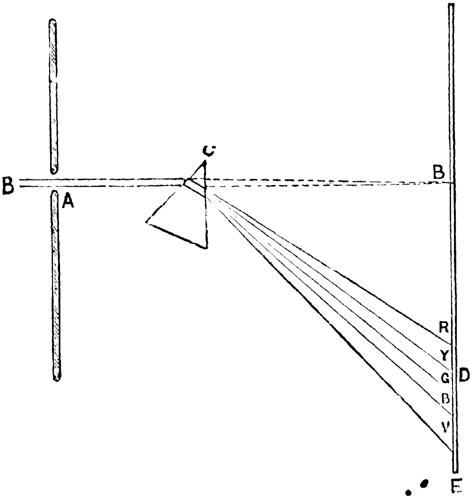

FIG 1.—Showing refraction of light and production of spectrum by means of the prism.

But it is difficult to believe that no such thing as light and colour exist in the external world, and that they are merely delusions or sensations produced within the eye and the brain. As a clear understanding of this initial fact is very essential, it may be desirable to state here briefly the theory of light as now universally accepted. Light has been described as "*not a thing, but rather a condition of things*".

It is an established law that energy is convertible into heat, and the heat may be so intense as to make the substance glow with a dazzling light. This luminosity is but the visible exhibition of the intensely violent agitation or energy existing among the particles or molecules of the body emitting the light The sun is such a luminous body. It is very evident that whenever there is intense molecular disturbance, or vibratory motion, the vibrations will radiate in all directions, like the undulations on a pond of water into which a stone has been thrown The water itself does not move forward, but acts simply as the medium through which is propagated the agitation set up by the energy of the falling stone

A similar condition of things, but on an infinitely stupendous scale, is set up by the sun That glowing orb is radiating its energy into infinite space, and as water was required, in the case of the pond, to transmit in undulations the agitation produced by the stone, so philosophers have assumed that the whole universe is pervaded by an extremely subtle tenuous medium—*the ether* which transmits the energy of the sun in vibratory movements or waves These travel at the stupendous speed of some 186,000 miles per second of time. The waves of this hypothetical or light-bearing medium—known also as the *luminiferous ether*—during their swift journey through space cannot be termed *light* in the true sense of the word It is only when this rapid wave energy *reaches the eye and excites the delicate membrane of the retina* that it becomes transformed into the visible in the shape of light and colour (see § 5)

In the same manner, we cannot describe a cricket ball coming flying through the air as *pain* coming towards us, its force is transformed into pain only after it strikes us and we feel it. But the manner in which this "wave energy" can be translated by the retina and brain into the sensation of light and colour is a mystery which may never be solved.

Science cannot explain it, and, as Professor Tyndall says, "when we endeavour to pass from the phenomena of physics to those of thought, we meet a problem which transcends any conceivable expression of the powers we now possess. We may think of the subject again and again—it eludes all intellectual presentation; we stand, at length, face to face with the incomprehensible."

§ 2. All that we do know is that the sensation of light arises from the action of these mysterious "ether waves" upon the sensitive organism of the eye; but what the true nature of that action is, has not yet been determined. Some scientists consider it to be a purely electrical action; others deem it a chemical one—and probably it may be both. That these waves of radiant energy, or light, have a chemical action is, of course, well known, as from this property arises the art of photography. If sunlight falls upon the green leaf of a plant, chemical action is again manifested, and scientists, with suitable apparatus, can show that light is capable of producing an electrical effect.

But of the great number of "ether" or "energy waves" which traverse space, only a comparatively small portion of them are appreciated by the organ of the eye, and are thus made visible.

For example, Fig. 2 illustrates the visible spectrum, consisting of all the colours from red to violet; but extending far beyond the extreme red, though invisible to the eye, is another series of rays, termed the heat spectrum. Beyond the extreme violet, also, are rays invisible to the eye, and, from their power of producing chemical action, are termed the chemical or "actinic" rays. It will be seen, therefore, that what we term the visible spectrum, extending from red to violet, is really but a small portion of the multitude of different ether waves.

No sensation of light is produced upon the retina of the eye unless the vibratory speed of these so-called waves lies within certain definite limits. The wave length of the extreme red rays is said to be about $\frac{1}{34000}$ of an inch, while that of the extreme violet is about $\frac{1}{64000}$ of an inch.

Light bears in this respect a close analogy to Sound, as no sensation of sound is produced unless the air-waves beat upon the drum of the ear at a certain definite rate.

The differently coloured lights we see in the spectrum have all different "wave lengths," and the length of the wave, or, in other words, the rapidity of its vibration, determines the colour of the light. The slowest visible waves are found at the extreme red of the spectrum, and, as their speed or "wave frequency" increases, we get the orange, yellow, green, blue, until we come to those of shortest wave length, *i.e.*, the violet. The wave length of the extreme violet rays is only about half that of the red rays, and they beat upon the delicate retina of the eye with double the rapidity of the red. Between these two extremes lie the various intermediate hues, orange, yellow, green and blue, with their various wave lengths, or "vibration frequencies," all merging beautifully into one another.

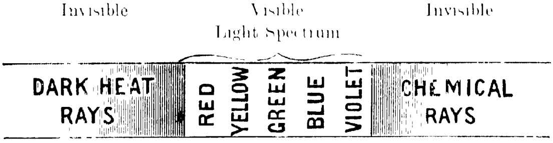

FIG. 2

It will be observed, therefore, that Seeing and Hearing are closely analogous, and that *colour* bears the same relation to light as *pitch* does to sound.

§ 3. As people's ears differ in regard to their sensibility for hearing sound, some hearing sounds of a very low or a very high pitch, inaudible to other ears, so also people's eyes differ in their range of sensibility to colours. The extreme limits of the spectrum to one observer are, in all probability, not exactly the same as to the eyes of another. It is reasonable to expect that the limits of vision of small animals and insects are not the same as those perceived by man, and that their eyes, being much more minutely and delicately constructed, will be sensitive to rays of shorter wave length than can be appreciated by human eyes. That this is actually the case has been abundantly proved by the researches of Sir John Lubbock (Lord Avebury), who has shown that ants and insects can perceive rays beyond the extreme violet, which are invisible to our larger and less sensitive eyes. For all that we know, some of the colours we see, such as red, orange and green, may be invisible to the eyes of some of the smaller animals, while their eyes can perceive colour beyond the extreme violet, invisible to man.

STRUCTURE OF THE EYE.

§ 4. **Eye Structure.** Before proceeding further to the perception of colour and its various phenomena, it may be well for us to refer briefly to the structure of the eye itself. We do not intend to enter into a minute description of the human eye, as the reader may obtain such in any text-book on optics, but we wish merely to point out a few of its principal features in relation to our subject of colour vision.

(a) *Eyeball.*—The human eyeball is nearly spherical in form, and about one inch in diameter. The orbits, in which the eyes move, are hollow cones of bone, wisely arranged in such a position as to admit of the widest range of side vision consistent with the power of binocular vision, *i.e.*, that of directing both eyes at once on a near object.

The eyeball in its orbit is surrounded with a bed of fat, so that it can move readily in all directions. Roughly speaking, the eye consists of three outer membranes or coats, and is filled inside with three humours, or liquids.

Fig. 3 will assist us in studying the more important parts of its structure.

(B) *Sclerotic.*—The first coat or outer membrane is the *sclerotic* (Sc. in Fig. 3), which constitutes about four-fifths of the posterior external coating. It is opaque, and forms what we term in ordinary language "the white of the eye."

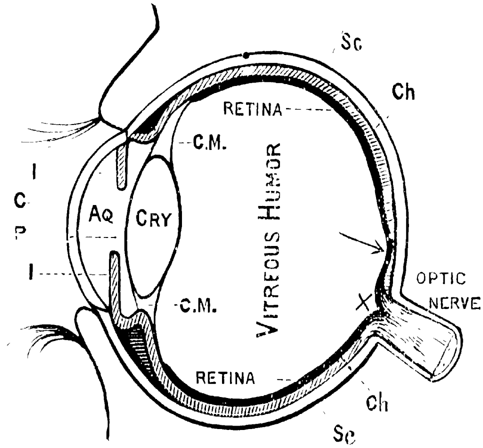

Fig. 3.

(C) *Cornea.*—Joined to this white opaque membrane, and immediately in front of the eye, is a transparent medium shaped like a very convex watch-glass (C.), and is termed the *cornea* from its horny-like nature.

On account of its transparency, the *cornea* cannot be well observed when looking straight into the eye, but may be best seen by looking at it from the side, when its watch-glass-like shape is readily observed.

(D) *Choroid.*—Under the *sclerotic* (Sc.) is another membrane containing the blood-vessels of the eyeball, and is therefore termed the vascular coat, or the *choroid* (Ch.), which comprises the iris. The *choroid* lies close to the inner side of the *sclerotic*, and the iris, or coloured diaphragm of the eye, is behind the watchglass-like cornea (see I.I. in Fig. 3). This choroid coat not only contains the wonderful network of blood-vessels of the eye, but it is also lined with dark-coloured or black-pigment cells. This makes the interior of the eye dark like a camera. These black-pigment walls absorb all excess of light that would arise from reflection and diffusion inside the chamber of the eye, and would thus cause dim and inaccurate vision. Persons whose eyes are devoid of this black protective lining are termed Albinos (see the Iris, § 7 (L)).

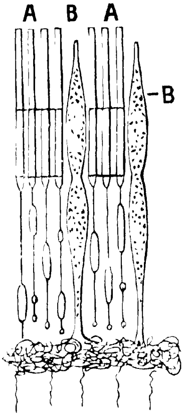

FIG. 4.—Portion of retina showing rods (A) and cones (B).

§ 5. (E) **Retina.**—The third coating, or inner membrane, is the *Retina* (see in Fig. 3). This is the most important part of the whole eye. It is this wonderful nervous membrane that receives the impressions of the waves of radiant energy (see § 2) and transmits them to the brain, where they are translated into Light and Colour. Although the retina is only about the $\frac{1}{100}$th part of an inch in thickness, just about the thickness of ordinary writing-paper, it is found to consist of no fewer than nine different membranes, or nerve layers, of marvellous intricacy and delicacy. Without going into details, it may be said to consist principally of two delicate structures, one portion of connective tissue being in contact with the vitreous humour. This is termed the inner, or anterior, membrane. A second, or outer, membrane consists of layers of peculiar, cylindrical nerves, some blunt and others pointed at the ends, which from their shape are termed "rods" and "cones". This layer is in immediate contact with the pigment layer of the choroid coat (Ch.) Fig. 4 gives a section of this part of the retina, showing the rods (A) and cones (B). These "rods" and "cones," as they are termed, play a most important part in the perception of light and colour, and recent investigation has proved that the sharp-pointed nerves, or the "cones," determine the nature of the *colour* of the object seen, while the "rods" are sensitive only to the *light and shade*.

The remarkable fact has been discovered, also, that animals, which, from their habits, do not require colour-perception, such as the burrowing and nocturnal animals like the mole and hedgehog or the bat and the owl, have no cones in their retina, only the rods, as shown in A, Fig. 4, being present.

(F) *Yellow Spot.*—In the human eye the most sensitive part in the retina for perceiving colours is at the arrow point shown in the diagram, Fig 3, where there is a peculiar depression in the retina. This spot is termed the *macula lutea*, or the "yellow spot" from its colour. It is directly opposite to the middle of the pupil. The depression itself is known as the *fovea centralis*, and is the only part of the retina which admits of clear and distinct vision.

For example, in reading or looking at a picture or landscape, we find that we can see distinctly only one small portion at a time. It is necessary to move the eyes to and fro to see every part clearly; we must place the eye in such a position that the image falls upon this sensitive spot; otherwise we obtain a general, but more or less hazy, indistinct view.

It is a remarkable fact that at this certain point the most acute portion of the retina, the "cones," or colour-perceiving nerve fibrils, are very numerous and closely set, while the rods are very few, and situated round the margin of this yellow spot.

(G) *Blind Spot.*—It is rather curious, also, that not very far from this, the most sensitive portion of the retina, is a spot entirely insensible, or blind, to light. This "blind spot," as it is termed, is situated at that portion where the optic nerve enters the eye at the "X" mark in illustration, Fig. 3. Here the nerve fibres are devoid of rods and cones. One would naturally think that this portion, where all the nerves are gathered together, should be the spot of most acute vision. The existence of this blind spot, as no doubt most of our readers already know, can easily be demonstrated by closing the left eye, and looking with the right at the cross in Fig. 5, at a distance of about twelve inches. The cross and the round spot will be both visible. Then bring the page gradually nearer to the eye, still keeping the gaze fixed steadily on the cross mark, till the page approaches to about seven inches from the eye, when the retinal image of the round spot falls upon the entrance of the optic nerve, and the black disc will become invisible. On bringing the page still nearer to the eye the disc reappears, after its image has passed over this "blind spot" of the retina. This may be readily understood by studying the simple diagram, Fig. 6.

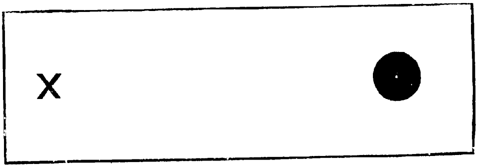

FIG. 5

§ 6. The three Liquids, or Humours, present in the eye are termed the aqueous, crystalline, and the vitreous.

(H) *Aqueous.*—The *Aqueous Humour* (Aq. in Fig. 3) consists of nearly pure water, and occupies the space between the cornea (C.) and the crystalline lens (Cry.).

(I) *Crystalline.*—The *Crystalline Humour* or lens (Cry.) is a firm, elastic, gelatine-like substance, shaped biconvex, like an ordinary "magnifying glass." The convexity of this lens can be varied by the action of the ciliary muscles (see C. M.), and in this way near and distant objects can readily be focussed. With the advancement of age, however, the lens loses its elasticity and becomes denser. It is then not possible to increase its convexity in order to focus near objects, and resort must then be made to convex glass spectacles. The muscular effort necessary to focus the eye is technically termed "accommodation."

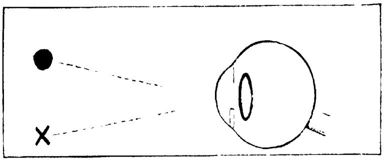

FIG. 6.

Sometimes, as the crystalline lens grows dense with age, it also acquires a yellowish tinge. This alters considerably the appearances of colours, especially those belonging to the blue and violet class. The yellow tinge absorbs a certain amount of its complementary blue, and an observer having eyes so affected will see colours slightly altered by their having a slight deficiency in their blue rays. The effect is similar to that of viewing through a faintly tinted yellow glass or film.

Artists or colour-matchers, whose eyes are affected in this manner, will, in matching colours or in painting, make their shades somewhat bluer and colder than they really appear to the normal eye, the crystalline lens of which is colourless. The cold bluish effect of the later paintings of Mulready and Turner is attributed by Leibreich to this yellowing of the lens by age. This interesting question is, however, treated more fully in Chapter VI., when dealing with the colour-vision defects of the eye (see §§ 46, 47).

(J) *Vitreous.*—The third or *Vitreous Humour* occupies about four-fifths of the interior of the eyeball, and derives its name from its resemblance to liquid glass.

It is a colourless transparent jelly, beautifully adapted to support the delicate membrane of the retina (R.R. in Fig. 3) and to prevent it from receiving any sudden jar or shock.

§ 7. (K) *Pupil.*—The round opening in front of the eye (see P) through which the light passes into the interior of the eye is termed the *pupil*, and by the action of the muscles of the iris (I.I.) the pupil has the property of regulating the amount of light by contracting or dilating. If, for example, we look towards the sun, the electric arc, or any source of strong light, the pupil of the eye contracts until it is only a very small opening, and thereby shields the eye from the excessive light. If we pass into a dark or dimly-lighted room, the pupil dilates in order to let in as much of the weak light as possible.

The pupil of the human eye always appears black, except in cases of peculiar eyes, such as observed in the Albino; but the eyes of certain animals, like the cat, dog, wolf, the lion and tiger, may be seen to glare with a strange "uncanny" light, even in the dark. This was for a long time considered to be a real light, emanating from the eyeball itself, and produced by the anger or excitement of the animal; but investigation has now shown it to be merely a reflection from a peculiar patch of a metallic-like surface on the choroid coating inside the eye.

(L) *Iris.*—The *iris* (see I.I.) is like a curtain stretched across the interior of the eye, and gives to the eye its own characteristic colour. When we speak of brown, blue or grey eyes, we refer to the colour of the iris.

If, however, the colouring matters normally present in the iris be absent, and also the black pigment in the choroid coating, then the eyes appear pink from the light reflected through them from the blood-vessels in the choroid membrane. Such an abnormal condition of eye is seen in the ordinary white rabbit, and also in people who are Albinos.

The eyesight of an Albino is always defective, and they are painfully sensitive to any little excess of light, because their eyes are devoid of the natural dark pigment, which forms so wonderful a protection in the normal eye.

(vi) *Optic Nerve.*—The optic nerve (O.N., Fig. 3) consists of all the delicate nerve filaments, or fibres, from the retina bundled together into what has been graphically likened to "a many-stranded cable," which conveys its sensation from the retina to the brain, where it is immediately translated in some mysterious manner into what we term light and colour.

The foregoing brief and imperfect sketch of the more important features of the eye may help us in our further study of the perception of colour. The eye, notwithstanding all its ascribed faults as a purely optical instrument, fulfils its proper functions in a truly marvellous manner. Indeed, the deeper we study its wonderful construction and properties, which finally baffle investigation, the more we become convinced that there must be wise reasons as yet unknown to us to account for what the scientist lightly terms its "blemishes".

PERCEPTION OF COLOUR

§ 8. **Perception of Colour.**—We have already observed that a beam of white light (B, Fig. 1), when decomposed by means of the prism (C), is found to consist of six fundamental colours—red, orange, yellow, green, blue and violet—all merging beautifully into one another to form the *spectrum* (D). It will be observed, also, that the longest colour waves, or those of slowest beat, *i.e.*, the red, are the least refracted, or bent, during their passage through the prism; while the coloured light of shortest wave length, *i.e.*, the violet, is the most

…ected. Between these two extremes are the various different colours, all varying in degrees of refrangibility or wave length.

Every ray of different colour, or what is termed *refrangibility*, seen in the spectrum is a simple, homogeneous colour, and cannot be further decomposed. If, for example, we throw the spectrum upon a screen and then cut a hole in the screen, in the green portion as shown in Fig. 7, we obtain a ray of green light, but on passing this green light through a second prism (D) we find it cannot be further decomposed into yellow and blue as we might expect. Every spectrum lour is simple, but physiologists, after long and laborious research on the structure and properties of the eye, have been led to the conclusion that all the colours of the spectrum can be reduced into *three elementary* or *primary sensations*.

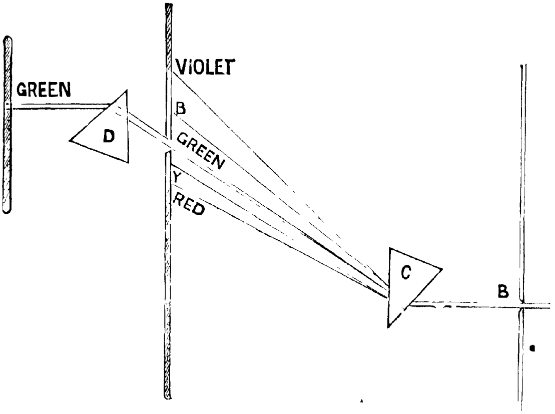

FIG. 7.—Showing homogeneous nature of spectrum colours: green not further decomposed.

§ 9. **Primary Colour Sensations.**—What these three primary colour sensations are has been a moot point for long, but scientists are now almost unanimous in selecting **Red, Green and Violet** as the fundamental colour sensations, and on these the most reasonable theory of colour has been established.

A German physicist named Wunsch, in 1792, was the first to select this triad, and the famous Dr Thomas Young, some ten years afterwards, independently adopted the same three primaries, and enunciated his theory of colour, which, after lying neglected for many years, was revived, and further developed, within recent years by Helmholtz, Clerk-Maxwell and others, and forms what is now termed the Young-Helmholtz theory.

It is conjectured that the retina, which, as we have seen, is an exceedingly complex structure, consists of a vast assemblage of minute nerve fibrils of three different kinds one set very sensitive to the red light, but not so sensitive to green and violet, a second set very sensitive to the green waves, but stimulated only in a small degree by those of red and violet, and a third set of nerve fibres readily sensitive to the violet waves and less to the red and green. When all the three nerve fibres are equally stimulated, the sensation of white light is produced; but if the red or the green set of nerves be more affected than the violet, then the impression of a red or a green, mixed with a proportion of white, is the result

As we have already stated in § 5, it seems to be proved beyond a doubt that the peculiar set of pointed nerves in the retina termed "cones" have the special function of perceiving the colour sensations, while the "rods" determine only the light and shade (see Fig 1)

This theory of colour vision is considered by physiologists to be quite in harmony with the structure of the retina as revealed by the microscope; and it also gives a reasonable explanation for the phenomena of "after-images," or complementary colours, dichromic vision, and other curiosities of colour-perception.

As dichromic vision, or what is generally termed *colour-blindness,* is of great interest to the colour-matcher, it will receive special attention in a subsequent chapter (see Chapter VI., §§ 48-50).

§ 10. **Complementary Colours.**—If we look steadfastly at a bright red colour for some time, such as found in dyed pattern Nos. 1 and 3, in Appendix, and then immediately view a white sheet of paper, we observe a bluish-green image of the red-coloured object. This is owing to the set of red sensitive cones or fibrils being fatigued or paralysed with the too long action of the red light; and on viewing white, only the two remaining colour nerves act, namely, the green and violet, which combine and form the bluish-green of the after-image. As the red nerve fibre gradually recovers its powers of perceiving the red element in the white reflected light, the blue-green image fades away, and the paper again appears white.

Another example may be found in the beautiful, bright pink dye Rhodamine (see dyed pattern No. 2), which, after viewing for a few seconds, gives a bright yellow-green after-image. This pink colour of Rhodamine consists principally of red and violet rays, which stimulate and fatigue the red and violet sensitive nerves. On viewing a white sheet of paper, therefore, the eye perceives a *green* image, as the green nerve is the only one left unexhausted. Green is, therefore, the "complementary" colour to pink.

By gazing steadfastly on the bright orange in dyed specimen No. 4, and then turning the eyes immediately to a white sheet of paper, we observe a greenish-blue after-image. In viewing orange not only are the red sensitive nerves acted on, but also the green nerves to a much less extent. The nerve fibrils that are left active after gazing at orange are, therefore, the violet and also to a considerable degree, the green ones. Consequently, the after-image, or complementary, to orange is violet, plus a portion of green, which goes to produce a *greenish-blue*, as we have already observed.

Yet another instance may be found by viewing a bright blue such as the beautiful blue seen in dyed specimen No. 5 (Night blue). This gives a red-tinged after-image, due to the fact that in viewing the blue only the green and violet nerves are affected and fatigued; consequently the green and violet lights reflected from the white paper are no longer perceptible, but the remainder of the white light, i.e., the red rays, stimulate the active red sensitive nerve, and produce the complementary red image as observed.

The following pairs are complementaries —

Red	and	Blue-green
Orange	,	Greenish-blue
Pink	,,	Yellow-green
Orange	,,	Green blue
Yellow	,,	Blue.
Green yellow	,,	Violet
Green	,,	Purple
Yellow-green	,,	Crimson

§ 11. The proportion of stimulation of the three sets of colour sensitive nerves may be represented diagrammatically by means of curves drawn on the chart of the solar spectrum No. 1, Fig 8, for example, represents the three sensations as drawn by Helmholtz. The lines A, B, C, D, etc., represent the well-known fixed lines of the solar spectrum. In this diagram it will be observed that Helmholtz gives the three colours, red, green and blue, all equal luminosities The sensation of yellow is produced by the combined action of the red and the green colour sensations Diagram 2 represents the colour sensations as represented by Dr Koenig, and are known as Koenig's curves. They were made after a great many experiments, not only with normal colour vision, but with those who were colour-blind. No 3, Fig. 8, gives the curves of colour sensations as formulated by Clerk-Maxwell.

It will be observed by carefully comparing these three charts representing the three colour sensations, as formulated by these expert physicists, that they all slightly differ, more or less, from each other; so that the question of the exact locality on the spectrum of the true fundamental colour sensations is still uncertain.

Unfortunately in a single chapter we cannot enter further into the absorbing study of colour vision, and must refer the student to the several excellent manuals dealing with colour physics. The foregoing pages, however, may act as a useful introduction to our subject of colour-matching, and may also

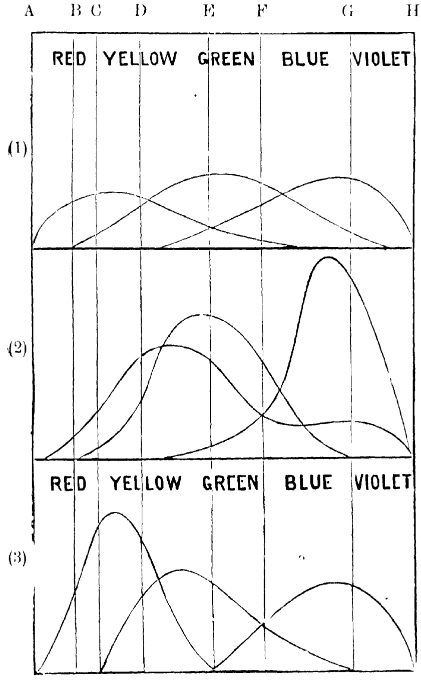

Fig. 8.

help the colourist to understand a little—a very little—of that mystery surrounding the simple faculty of perceiving colours.

For certain abnormal conditions of the eye, of much interest to colourists, such as yellowing of the lens, colour-blindness, etc., consult Chapter VI., §§ 46-50.

CHAPTER II

DAYLIGHT FOR COLOUR-MATCHING

DAYLIGHT STANDARD—DIFFUSED DAYLIGHT—DIRECT SUNLIGHT—REFLECTED BLUE SKYLIGHT—INTERFERENCE OF LIGHT—SELECTION OF A PURE LIGHT—ROSY MORNING LIGHT—VARIABILITY OF DAYLIGHT

§ 12. Next in importance to the question of colour-perception is that of the daylight itself, which illuminates the colours. It is always necessary to pay careful attention to the nature of the light employed in colour-matching, as the slightest tinge of colour present in it gives to the shades examined a decidedly different hue. After a little experience in the careful examination of colours, it will soon be observed that ordinary daylight is very far from being an ideal illuminant as regards whiteness and uniformity of quality. Some days it is found to be slightly reddish or of an orange hue, and at other times it possesses a predominance of the blue and violet rays. Indeed, where the utmost scientific accuracy is essential, as in many experiments in relation to colour physics, the daylight, as a standard, has to be discarded as untrustworthy, and the steadier and more uniform light of the electric arc substituted. It will be observed, however (see § 57), that the standard of quality of the arc light is slightly different from that of good daylight. Although the ordinary sunlight cannot be regarded as an altogether ideal illuminant for the scientist, owing to its changeable nature, it is, nevertheless, the universal, and, indeed, the only applicable standard for such practical colourists as the dyer, colour-mixer and calico printer. It behoves us, therefore, to study carefully its varying moods and do our best under the circumstances.

§ 13. **Pure Daylight.**—The white diffused daylight in early summer (about the month of May), and coming from a northerly direction, has been chosen, among colourists, as the standard of a good, pure daylight, as it possesses the necessary whiteness and purity for showing all colours in their truest aspect. The reason why the *north* light should be preferred is because the light coming from that direction is always the steadiest, and, being thoroughly mixed or "diffused," is of a purer and whiter quality than from the other directions.

Mr J. W. Lovibond has shown in his valuable work on the *Measurement of Light and Colour Sensations* that there is no light so pure and white as that from a white mist (sea fog), and he adopts it as his standard normal white light.

The light directly transmitted from the sun is of a "warm," or orange tinge; while that reflected from an open blue sky has a predominance of the rays found at the other end of the spectrum, namely, the blue and violet. These two coloured lights, the orange and the bluish-violet, are complementary to each other, and when they are combined or "diffused," together the result is a pure white light.

Complementary coloured *lights*, it will be remembered, produce whiteness, while with complementary coloured *dyes*, or *pigments*, greyness or black is produced. It will be observed, therefore, that the ordinary diffused daylight is generally of a very fair quality of whiteness, and well suited for the examination of colours.

The light reflected from a white or pure grey sky, from a bank of white cloud, or that transmitted through certain degrees of mist often prevalent in Scotland, are all of a good white quality, well adapted for the purposes of colour-matching.

§ 14. The best month for good sunshine is May, when it reaches its maximum amount for the year. June, July and August are the next best months for quantity, but generally towards August the atmosphere and the light become hazy and duller in quality. As might be expected, the darkest month of the year is November, when the sunlight reaches its winter minimum. The sunshine chart represented in Fig. 9 has been prepared by the writer from the average results of some thirty observing stations throughout Great Britain and Ireland. The sunshine throughout one year,[1] counting the total as 100, was found to be as follows:—

January.	February.	March.	April.	May.	June.
3	7	15	26	40	53
July.	August.	September.	October.	November.	December.
65	78	86	95	97	100

From these figures it will be observed that, of the total sunshine for the whole year, the month of

January	gives	3	per cent.	July	gives	12	per cent.
February	,,	4	,,	August	,,	13	,,
March	,,	8	,,	September	,,	8	,,
April	,,	11	,,	October	,,	9	,,
May	,,	14	,,	November	,,	2	,,
June	,,	13	,,	December	,,	3	,,
					Total	100	

From the above can be drawn the chart, Fig. 9, which shows at a glance the varying percentages of sunlight for the months of the year. It might almost be taken to represent not only the quantity of sunlight, but the *quality*, or purity of the light for colour-matching purposes, as the best months for colour examination are from April on to August, and the poorest are those where the daylight is scarce and of inferior quality, namely, from October on to December, January and February. From the chart it will be observed that there is a decided minimum in winter, from November to January, then a steady increase through the spring months to the maximum in May, i.e., 14 per cent. Then there comes a secondary minimum in June and July, to another maximum in August, when there follows a great fall from 13 per cent. to 8 per cent. in September. A slight increase in October is followed by the fall to the winter minimum in November, the darkest month in all the year

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[1] According to Mr. H. N. Dickson, F.R.S.E., in *Trans. Scot. Geographical Assoc.*, 1893.

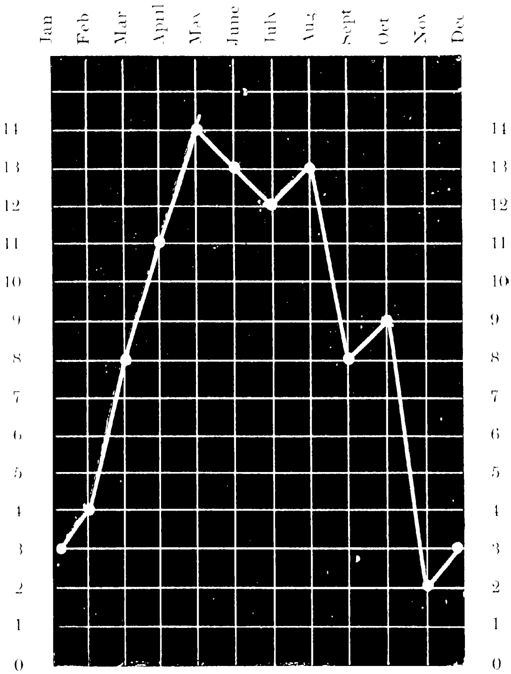

Fig. 9.—Sunshine chart, showing percentage of sunshine throughout the year for Great Britain

§ 15. **Diffused Daylight.**—The matching of colours, especially dyed on wool and silk, is a most difficult task in the dark months of the year; but the dyer and colour chemist can receive invaluable aid during such times from the electric arc, the Dufton-Gardner improved matching light, and also the magnesium light. These, however, will be considered in their proper places among the artificial illuminants (see §§ 57-59). It will be observed, therefore, from what has just been stated, that the ideal daylight for the colour-matcher is a north light, during the clear months of May and June, May especially.

But, unfortunately, all practical colourists, such as dyers, calico printers and colour-mixers, cannot wait for ideal weather to match their various shades, but must make as perfect a match as possible all the year round, and in all sorts of daylight and weather. It is here that much of the difficulty of colour-matching is experienced, as many of the delicate fashion shades are found to alter considerably in the different qualities of daylight. The writer, for example, has often observed that two shades which appear a perfect match one day will appear "off the match" the next day, and this difficulty, which sometimes proves exasperating, is experienced very often by silk dyers. Shades dyed on silk, as we shall observe later on, are more sensitive to the changes in the quality of light than those dyed on any other fibre (see §§ 38-51).

The following few hints, with the assistance of the diagrams, may prove of interest in the selection of the best light for colour-matching.

The circle (Fig. 10) may be taken to represent the sky with its four cardinal points, North, South, East and West. It may readily be observed why the north light is steadier and more reliable in purity than that from any other direction. The light, in being reflected, is thoroughly mixed or diffused, and at no time of the day can there be found the yellowish or orange-tinged light of direct sunshine. From the east comes the morning sunlight, which is very often of a ruddy or "warm" hue, and this changes considerably the aspect of colours examined in it. From this direction, also, comes the rosy-coloured light of the dawn, the beautiful Aurora, which, however pleasing it may be to admire in an æsthetic sense, is nevertheless a most deceptive light to the anxious colour-matcher. We shall have more to say regarding this light as we proceed.

At midday the sun is due south, and shades cannot be matched accurately under its influence; but the light from the east, as well as the north, may then be used for colour examination. It will be observed from Figs. 10 and 12 that they are now both well-diffused lights.

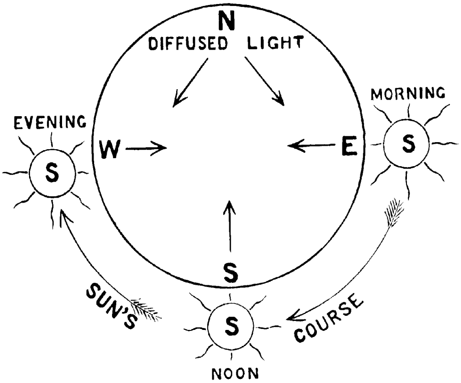

FIG. 10.—Diagram showing north light the steadiest and best diffused.

After midday the sun continues on its course to the west, and the direct or transmitted light during this part of the day is the most deceptive to the colourist, as it possesses a predominance of the orange and yellow rays, which alters considerably the aspect of dyed shades, especially those on silk and wool.

During this part of the day, however, from noon to evening, the light from the north, east and south-east are, under ordinary conditions, all well diffused, and of a fair quality of whiteness. It will be observed, therefore, that one window in a colour-matching laboratory is not nearly so serviceable as three or four windows facing the different directions. At certain times of the day the colourist must choose the windows best suited for his purpose.

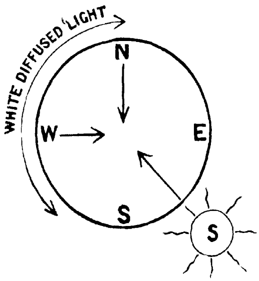

Fig. 11.—Forenoon.

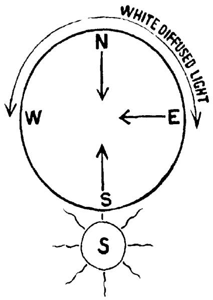

Fig. 12—Noon

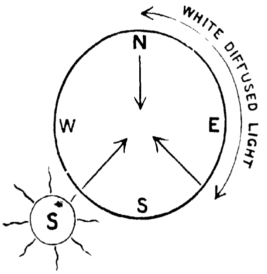

Fig. 13—Afternoon.

Simple diagrams showing best diffused light during the day.

Thus, in the forenoon, as will be seen from the simple diagrams, Fig. 11, the best diffused light comes from north and west; at noon, Fig. 12, when the sun is south, the best light comes from the north and east; in the afternoon, Fig. 13, the best diffused light is the north, east and south-east. They may be tabulated as follows:—

Best Diffused Lights for Colour-Matching.

Fig. 11. Forenoon = North and West.
„ 12. Noon = North and East.
„ 13. Afternoon = North, East and South-East.

From the above we learn that a north light is the best for colour-matching throughout the whole day.

§ 16. **Direct Sunlight.**—The excess of red and orange light, or what artists term the *warmth*, in direct sunlight, has long been observed by colourists, and its effects on the aspect of colours, especially those dyed on wool and silk, are very deceiving. Colours belonging to the less refrangible end of the spectrum, *i.e.*, the reds, orange and yellows, are all brightened and yellowed when illuminated with it; while those belonging to the other end of the spectrum, the blues and violets, lose their clear blueness of hue and appear duller and redder. A fine series of hues termed mauves, which are violets of a bluish cast, when viewed in direct sunshine appeared more like a class of magentas. The blue rays reflected by all such colours as violets, purples and mauves are lost in direct sunlight, and the predominance of orange rays in the light gives them the appearance of bluish reds or magentas. For this reason some of the finest colours, such as crimsons, blues, bluish pinks, violets and others of this class, cannot be properly examined in the direct rays of the sun. The effect produced is similar in kind, though much less in degree, to that of an ordinary artificial illuminant, and is caused by the deficiency in the light of the blue and violet rays, which are necessary to show the true aspect of all colours.

Ordinary white sunlight, as the reader is aware, consists of a marvellously balanced mixture of differently coloured lights—red, orange, yellow, green, blue and violet; but if the proportions of any of these coloured rays be altered or interfered with in the slightest, the resultant light is not white, but coloured by the predominating rays.

Thus, if a small portion of the red and orange rays be separated or detached from white sunlight, the remaining rays combine to form a bluish light. If some of the blue and violet rays be separated from white light, the resultant light will have a red or orange tinge, due to the predominance of these rays. It is owing to this separation, or what is termed "interference" of the blue and violet rays in the light passing through the atmosphere, that there exists an excess of red and orange rays in the transmitted sunlight. The denser the atmosphere is, the greater will be the amount of blue and violet light separated, and consequently the redder will be the transmitted light. This may be observed in the redness of the sun during a dense fog, or when it is low on the horizon, as at sunrise and sunset. Under direct sunlight blues of a somewhat reddish hue become redder, approaching more a blue violet, while violets lose their proportion of blue and appear like the purplish or red violets.

Various beautiful compound or tertiary shades, such as soft greys, buffs, drabs, olives, sages, etc., show a considerable difference in appearance in direct sunlight, as they lose their blue and violet constituents. But one advantage of the redness of direct or transmitted sunlight is the fact that it brings out certain little peculiarities of hue in many colours, which might otherwise escape detection. The orange-tinged light brings them out more distinctly. Thus, violets having a bluish cast, when compared with those having a reddish cast, in a white light show perhaps very little distinction, but in the direct sunlight they show a much greater divergence in hue; the blue violets become deeper and duller, while the reddish violets appear clearer and redder.

The slight differences between blue-greens and yellow-greens, or between reddish blues and greenish blues are much accentuated; the blue-greens becoming duller, while the yellow-greens become brighter and yellower; reddish blues become redder in hue, while the greenish blues keep a clear green-blue appearance. Similar changes in the aspect of colours, but in a much greater degree, are produced with any of the artificial illuminants, such as gas or lamp light, which possess a great excess of red and orange rays. These, however, are specially considered in Chapter VIII. on the artificial lights.

As every practical dyer and colourist knows, there are many compound shades, especially those dyed with aniline colours, which are very sensitive to the slightest tinge of colour in the daylight. A few such shades will be found in the dyed pattern plates at the end (see especially Nos. 6, 7, 8, 13 and 14), and if the reader views them first in good white light, then in direct sunlight, he will be astonished at the differences in their appearance. Dyed colours on silk and wool are far more liable to alter in hue, under such conditions, than the insoluble pigment colours painted or printed on paper.

As we shall see, in Chapter IV., the lustre of the fibre and the optical properties of the dye stuff both play a part in the abnormal differences in hue often observed in dyed fabrics under an orange-tinged light like direct sunlight.

§ 17. **Blue Skylight.**—The light reflected from the open blue sky shows a predominance of the blue and violet rays, and is, therefore, a complete contrast to direct sunlight. They are, in fact, complementary to each other. Blue skylight has the opposite effect on colour appearances to that of transmitted sunlight. It deepens and enriches those colours belonging to the more refrangible end of the spectrum, the blues, cyan-blues and violets; while the red, orange and yellow at the other end of the spectrum become dulled and flattened in their appearance. The blue quality of this light shows many of the colours to the best advantage, especially those which owe their characteristic beauty to the green and blue light they reflect. There are certain greenish yellows, for example, such as chinoline or quinoline yellow, uranin, nitrazine, auramine and napthol yellows, which show a beautiful and delicate lemon hue in blue skylight, which is quite lost in a clearer or yellowish light. Many of the beautiful hues of bluish red, such as magenta, crimson, and the pinks derived from the phthaleins, Eosine pink, Rose Bengal, Phloxine, Rhodamine, etc., appear to advantage in a blue skylight, as it shows up their delicate bluish bloom which constitutes their characteristic beauty.

It will be observed, from the foregoing, that direct sunlight and blue skylight are exactly opposite in their predominating hue and in their influence on colour appearances.

This explains why coloured materials like dyed fabrics—wool and silks especially—change so much in their aspect when viewed first in the one light and then immediately in the other. The colour contrast of the two lights becomes very apparent when objects in nature happen to be illuminated by both of them at once. Thus, an object standing in the strong sunshine is itself ruddy, or what artists term "warm" in hue, while the shadows, which are illumined only by the blue skylight, are of a bluish violet hue.

This colour contrast is also intensified by their being in juxtaposition. The different hues of ordinary daylight are shown often in snow scenes, and artists know how difficult it is to represent faithfully the surface of snow, with its many delicate variations in hue in its lights and shadows, arising from the "warm" direct light and the bluish reflected light from the sky.

At Fig. 14 we have a simple representation of the nature of these two qualities of light. (A) represents the spectrum of ordinary white light, showing all the colours from red to violet in their normal intensity. The letters A, B, C, D, etc., represent the well-known Fraunhofer lines, which are invaluable "landmarks" to the scientist and colourist. (B) represents the spectrum of direct, or transmitted, sunlight, and shows all the colours from red to green-blue in their normal intensity, the same as in the spectrum of white light; but from the blue to the violet end of the spectrum there is a deficiency or absorption of rays, which is here represented by shading. It is this absence of the due proportion of the blue and violet rays that gives to direct sunlight its ruddy orange hue.

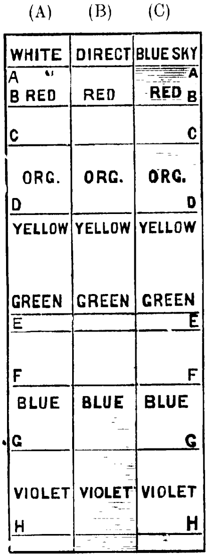

FIG. 14.—(A) Showing spectrum of pure white light. (B) Direct or transmitted light, showing slight absorption of the blue end. (C) Blue skylight, showing slight absorption at the red end of spectrum.

Spectrum (C) represents that of blue skylight, and shows the contrast to that of transmitted light (B). In blue skylight the rays from violet to yellow, at the line (D), are present in their full strength, but, from the orange on towards the red end of the spectrum, there is absorption shown by the shading. The absence of the red and orange-coloured rays gives to reflected skylight its bluish hue From this simple diagram it can readily be understood how blues and violets in direct sunlight (B) lose their blueness and appear redder, while reds and scarlets appear dull and flat when viewed in a blue skylight like that of (C).

If, during the summer months, it is found that the skylight windows of the matching laboratory admit the bluish light reflected from the deep blue sky, the slightest coating of a pure whitewash painted over the windows will greatly help to make the light purer and of a better quality for matching shades.

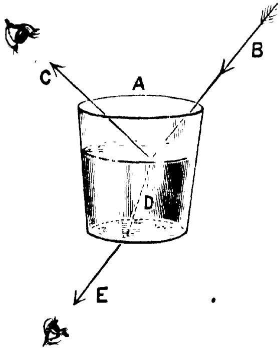

FIG. 15.—Diagram showing (C) reflected and (E) transmitted lights.

§ 18. **Interference of Light.**—Before proceeding further, it may be well to consider briefly the cause of this difference in hue between the transmitted sunlight and the reflected blue skylight.

In order to illustrate this, let us take a glass beaker or tumbler (A) containing pure water, as in Fig. 15. If a beam of white light (B) strikes the surface of the water at an angle, as shown in the illustration, the whole of the light rays do not pass through the water, but a portion of them is reflected from the surface, and can be seen at the point (C). The other portion passes through the water, being at the same time refracted or bent, as shown at (D), and can be seen as transmitted light at point (E). The light reflected from the surface at (C), and that transmitted through the water at (E), are both white lights.

If, however, we now add to the pure water a few drops of some liquid that creates a slight turbidity, a drop or two of milk, for example, or of soap solution, or resin dissolved in spirit, a "milkiness," or opalescence, is produced. On placing the glass against something dark or black, so that the liquid is seen only by reflected light, it will be observed that the liquid is of a decidedly *bluish* hue; while the transmitted light, seen by viewing through the liquid as at (E), is of a dingy *orange* hue. The turbid medium has "interfered" with, or decomposed, the white light during its passage. The infinitesimal particles, or globules, in suspension in the liquid have the power of reflecting the blue and violet rays of the spectrum, and these are separated out and reflected back to the eye, giving the liquid the bluish appearance. The remaining light is transmitted through the turbid medium, and, being deficient in the blue and violet-coloured rays, assumes a dull orangy-red hue from the predominance of these rays. In other words, the transmitted light is white light, minus a proportion of blue and violet light, lost in reflection. In this simple experiment, then, we have reproduced, in a crude way, the orangy hue of the transmitted sunlight, and the blueness of the reflected skylight, due to the dust particles in the air.

In nature, where we view these colours in their sublimest aspect, the atmosphere plays the part of the turbid medium, and the denser or more turbid the air becomes, the deeper orange or red is the transmitted light. This is observed in a thick fog, or when the sun is setting and struggling through an increasing thickness of atmosphere. At such times the sun assumes a fiery red appearance like a ball of vermilion.

The beautiful blueness of the sky is attributed to the opalescence of the atmosphere viewed against the dark background of infinite space through which the world moves.

We have already observed that if the orange transmitted light and the bluish reflected light be re-combined, they produce again white light. Hence the fair degree of whiteness of the ordinary diffused light of day (see § 15).

§ 19. **Selection of a Pure Light.**—From the preceding pages it must be observed that the selection of a pure white light is a question of the utmost importance to every colour-matcher. When the light cannot be obtained directly from the north sky, by means of roof or side windows, particular attention must be paid to the outward surroundings of the colour-matching laboratory.

§ 20. If, for example, there should be a considerable surface of green foliage in the shape of trees, shrubs or fresh green grass immediately in front of the windows, the light, which enters the laboratory during sunshine, will be tinged with a greenish hue reflected from the surrounding foliage. Light of this quality flattens, or dulls, all those colours belonging to the red end of the spectrum, *i.e.*, reds, scarlets, orange and yellows. Some time ago the present writer had an experience with a light of this sort. While examining a selection of scarlets dyed on wool, they appeared to him much duller than usual, and wanting in vigour. Yellows also assumed a flatter or saddened appearance. After some little difficulty, it was found that a large tree in front of the matching window was the cause of the trouble. The tree stood in the full sunshine, and reflected into the room a light strongly tinged with green. Such a light is unsuitable for careful colour-matching. In speaking of this, it may be interesting to mention that Tennyson, who was always a keen observer of nature, alludes beautifully to the greenish light reflected from grass and foliage; where, on the white chalk roof of the hermit's cell—

> The green light from the meadows underneath
> Struck up, and lived along the milky roofs[1]

§ 21. It has been observed, also, that any strongly coloured surface in front of the matching windows, such as a red-brick wall, or the terra-cotta painted side of a house, when illumined with sunshine, reflects a considerable amount of reddish light. Not only the outside surroundings, but also the inside of the laboratory may require a little attention. No strong, decided colours should be used in painting the walls, but a soft neutral grey will be found to have the best effect in the colour-matching room.

In the dark months of the year it is advisable to keep all the matching required until the middle of the day, when the daylight is at its best. In the months of January and February the light in the afternoons, after the sun has set, is of a very blue quality, as the only source of light is that reflected from the bluish grey sky. When the colourist is in difficulty with the bad quality of the light, and wishes to examine some shades, he will find the magnesium light of great assistance to him, if the electric arc or the Dufton-Gardner light is not at his disposal. For the use of these illuminants in colour-matching see Chapter VIII., §§ 57-59.

§ 22. **Rosy Morning Light.**—Though every colour-matcher and dyer knows that from forenoon to midday is the best time to examine shades, yet this rule cannot always be observed. In the hurry and bustle of business, nowadays, we cannot wait patiently till the best part of the day to do our matching. During the morning of the dark months, from November on till March, the sky is often suffused with an orange or a rosy pink light—the Aurora—which, though beautiful to look at, gives most misleading results to the colour-matcher. Even an ordinary coal gas flame looks white and pale in the rosy light of a November morning This might be guessed from the ruddy appearance of everything in such a light: face and hands assume quite a rosy hue. The writer had a striking illustration of the deceptive effects of this rosy morning light when examining a series of differently composed shades Some were dyed with the natural dyestuffs, while other shades, matching the former very closely, were dyed with some of the anilines. In good daylight the several pairs of shades very closely resembled each other; but to his astonishment, when examined in the morning light, they presented a totally different appearance, and not the least like each other.

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[1] *Launcelot and Elaine.*

For the cause of such differences in the behaviour of apparently similar colours we must examine with the spectroscope the optical structure of the dyes themselves (See Chapter IX.)

A pair, which matched closely in good daylight, were reddish drabs, dyed in the one case with archil, acid indigo extract and fustic, and the other with orange, patent blue, and an aniline red. In the ruddy light of the morning the first shade presented a *russet* appearance, while the other, dyed with the anilines, appeared a *greenish drab*. Such a quality of light, therefore, is quite unsuitable for the examination of dyed shades. In two or three hours afterwards, when good daylight had fully come, the shades referred to *closely matched* each other.

Two dyed shades closely resembling in properties, and behaviour those just described will be found in dyed patterns Nos. 13 and 14. (See Appendix.)

As such perplexing phenomena are often observed by the practical dyer, we have studied them more fully under Chapters VII.-IX., when dealing with the aspect of colours under the artificial lights.

§ 23. From what has been stated in the previous pages, it will be observed that the quality of daylight forms a very important study to every dyer and colourist who endeavours to see his shades in their truest aspect.

Direct sunlight or blue skylight, a rosy morning or a sunset, a warm hazy day or a dense fog, certain coloured surroundings without and within the laboratory, all tend, more or less, to affect a change on the true aspect of dyed colours, by altering the proportions of the coloured rays which they reflect.

CHAPTER III.

COLOUR CONSTANTS — HUE — LUMINOSITY — PURITY — EXAMINATION OF BRIGHT COLOURS—AID OF TINTED FILMS—SIMULTANEOUS CONTRAST — MATCHING DIFFICULTIES ARISING FROM CONTRAST

§ 24. In making an examination of any colour, there are three outstanding characteristics, or what are termed *Constants*, which claim attention. These are: (1) *hue*, (2) *luminosity*, (3) *purity*.

Hue.—The hue of a colour is that excessive predominance of one or two of the simple fundamental colours over the rest, and which gives it the distinguishing colour sensation. In common language it is simply understood by the term "colour," such as a red, orange, violet, green or blue. The purest standard of fundamental colours is that of the solar spectrum, where we find them all—red, orange, yellow, green, blue and violet—in their ideal beauty and perfection. The greater the predominance of any one of these in a colour, the stronger is the *hue* of that colour; but the original hue must always predominate.

For example, orange is a fundamental colour, but if it gets an addition of red to make it too red for pure orange, then it is an orange of a red *hue*; and likewise, if yellow be added in excess, it goes off from orange into a hue of yellow. *The predominating colour always gives the characteristic hue*; and, with a little careful examination, all the many soft tertiary or mode shades can be simplified into dulled or "broken hues".

A well-trained eye can distinguish the minutest differences in hue, which are too fine to accurately describe in language. It is here that the skilled colour-matcher and dyer can perceive differences in the hues of two shades, where an ordinary person would pronounce them to be exactly similar.

§ 25. **Matching the Fundamental Colours.**—In matching the fundamental colours, like red, orange, yellow, green, blue and violet, the colourist experiences little difficulty, as the many dyes of coal-tar origin, with their wonderful brilliancy, can supply all his requirements Before the introduction of the aniline colours, however, it was impossible for the dyer to make anything like a match to many of the colours, such as the brilliant greens, blues and violets; and pure colours like magenta, eosine pink, rhodamine and methyl violet were then quite unknown. But the difficulty of the present-day colourist and dyer is not in matching bright and luminous colours, but rather the dull tertiary shades, or mode hues, so much employed in the textile arts They are often most difficult to match accurately, and we shall have much to say concerning them in the following pages For the examination of bright colours see § 29.

§ 26. **Luminosity.**—This second colour characteristic, or constant, is generally termed the brightness, or the clearness, of the colour, and is distinguished by the amount of light reflected to the eye. The most luminous surface is of course *white*, which reflects all the incident light to the eye, and the several fundamental colours have varying degrees of brightness, or luminosity. Colours of a totally different hue, such as a bright red and a green, may appear equally luminous to the eye, and this is found to be quite in accordance with the results obtained by measuring, with a suitable apparatus, the relative luminosities of colours. The brightest part of the spectrum is the orange-yellow and orange; then come the greenish-yellow and the green.

Following the green in luminosity is the orange-red, then the red, blue-green and blue are all equally luminous; after which, come the blue-violet and violet, the lowest in the scale of luminosity. The following table shows, according to Professor Rood, the relative degrees of brightness of the spectrum colours:—

1 Orange-yellow (most luminous)
2 Orange.
3. Greenish-yellow and green.
4 Orange-red
5 Blue-green
Cyan-blue
Cherry-red (equal in luminosity).
6 Pure red
Blue (equal in luminosity)
7 Ultramarine blue
8 Dark red.
9. Blue-violet.
10 Violet (least luminous)

We have already observed that when highly luminous colours such as scarlet, orange, yellow, magenta, rhodamine and eosine pinks, etc., are viewed for some little time, the eye becomes fatigued from the excess of bright-coloured light, and is then unable to distinguish the nice differences in hue between such colours. They all appear duller to the eye. For the examination of such luminous colours see § 29

§ 27. **Purity.**—The purity of a colour, which is the third constant, is its freedom from admixture with white light, or with any other colour

The purest colours which can be obtained are those of the solar spectrum, produced by the decomposition of white light. If ordinary dyed colours and paints, which appear pure to the eye, be examined alongside their corresponding spectrum colours, it will be observed how thin and impoverished they look beside those of the spectrum. No ordinary dyes can match, for purity or brightness, the homogeneous colours of the spectrum. The reason for this want of saturation, or richness, in dyed colours is greatly owing to the amount of unchanged white light, which is reflected from the surface of the fibres, or of the material on which the colours are dyed.

The white light, mixing with the coloured light of the dye, causes it to become diluted and impoverished in purity.

But a pure colour is not necessarily a bright or luminous one, for, as we have just observed, many of the spectrum colours, such as blue, dark red and violet, though perfectly pure, are not very luminous.

On the other hand, many dyed colours appear very bright and luminous to the eye, and are yet not pure colours. Naphthol yellow and picric acid, for example, seem to the eye to be perfectly pure yellows; yet, on examination with the spectroscope, the light they reflect is found to consist of a large amount of red, orange and green rays as well as the yellow.

The beautiful aniline blues, which seem, to the unaided eye, almost as pure as the spectrum colours, reflect a considerable amount of red, green and violet light. Indeed, it is very seldom we can find among dyes a colour quite monochromatic, unless it be in a strong saturated solution, or a full rich colour dyed upon a lustred fibre like silk.

There is no colour stuff, however, either dye or pigment, which has been found in all circumstances to be perfectly pure or monochromatic; such perfection is found only in the spectrum colours.

§ 28. In examining the various dyed colours for their *purity* of hue, it is necessary to have, for comparison, a series of typical examples of as pure hues as it is possible to obtain. As already stated, the solar spectrum gives the perfection of hues in their ideal purity; but, as dyed colours cannot be made to match those of the spectrum, and as the spectrum itself cannot be kept in the laboratory all ready-made for immediate reference, it is more practicable for the dyer to have a set of dyed swatches of the purest hues that can be selected, and dyed on a fine lustred fibre like wool or silk. These fundamental colours can be made to range from the extreme red, through the various gradations of scarlet, orange-yellow, etc., on to violet. Such an artificial spectrum of dyed hues can be conveniently kept for reference and comparison, as occasion requires. It need scarcely be mentioned, also, that standard colours of all varieties must be carefully preserved from strong sunshine and dust.

§ 29. **Examination of Bright Colours.** – If highly luminous colours, such as magenta, orange, scarlet, bright pink, etc., be viewed in a good light, it is found that the eye becomes dazzled and fatigued from the continued action of the bright-coloured light upon the sensitive colour nerves of the retina. When the eye is in this fatigued condition it is unable to distinguish the nicer differences in hue among the colours examined, and requires to be restored to its normal condition again, either by rest, or by viewing the colour complementary to that which has produced the fatigue.

For example, when a number of highly luminous colours, such as scarlets, rhodamine pinks, orange, etc., such as found on dyed pattern plate 1 (see Appendix), are viewed for some little time, it will be observed that they become gradually duller in aspect, and many little differences in depth of tone and hue, which were perceptible at first, become no longer visible.

The colour nerves, or "cones," of the retina sensitive to the red rays have become exhausted from their over-excitement, and are no longer able to respond to the influence of the red light; and the eye spontaneously calls up the complementary colour, namely, greenish-blue. (See Chapter I., § 10.) On turning the red-fatigued eye to a sheet of white paper, a greenish or bluish-coloured after-image, or impression, is visible.

This "successive contrast" of colours, as it is termed, is observed after viewing any bright hue, and arises from that sympathetic action of the colour nerve fibrils, or "cones," present in the retina, as already described in § 10, page 1(

When the colourist has a number of such bright hues before him to examine, it is necessary to provide for this eye-fatigue by having a piece of material beside him of a colour complementary to those he has to examine. When the eye becomes fatigued, a short look at the complementary coloured material quickly restores the eye to its normally sensitive condition.

This phenomenon is well known in dyeing and textile departments, where bright colours have to be carefully examined for a lengthened period. In the Turkey-red warehouses, for example, those overlookers whose duty it is to inspect the dyed pieces are supplied with a piece of green coloured material, at which they must gaze occasionally in order to restore the retina to its normal colour-sensitive condition.

The following complementaries may be found useful for restoring the eye when colour fatigued :—

Bright Colours and their Complementaries.

Green-blue	is complementary to	Reds and Scarlets.
Turquoise-blue	,, ,,	,, Orange and Orange-yellow.
Blue	,, ,,	,, Yellow.
Violet-blue	,, ,,	,, Greenish-yellow.
Reddish-purple	,, ,,	,, Emerald-green.
Blue-green	,, ,,	,, Crimson
Green	,, ,,	,, Rhodamine pink.

If we gaze for some time on the bright colours to be found on plate 1 of dyed patterns, *i.e.*, (1) Scarlet, (2) Rhodamine pink, (3) Red, (4) Orange, the eye will readily experience colour-fatigue; and, by viewing a sheet of white paper immediately afterwards, the complementary hues, or the "successive contrast" phenomena, will be observed.

§ 30. **Aid of Tinted Films in Matching.**—But a much better method of examining such bright hues, whereby the discomfort of eye-fatigue can be avoided, is by viewing them through glass, or a gelatine film, tinted *bluish-green.* By looking through this blue-green coloured medium the eye is relieved of any fatigue, and, at the same time, the colourist can make much better examination of the colours. In this way a more correct judgment is obtained, as the bright hues are so "saddened" down that they can be viewed leisurely, and many little differences in hue and unevenness, or imperfections, in the dyeing or printing, can be detected, which would otherwise escape the naked eye.

As an example of how much changed in appearance the brightest colours become, when viewed through a green film, we may cite the following:—

Normal Colour.	*Aspect under Bluish-green Film*[1]
Bright Scarlets .	Soft shades of Brown
Oranges . .	,, ,, Old Gold
Eosines (yellowish) .	,, ,, Pinkish-brown
Eosines (bluish) .	,, ,, Magenta or Red Violets
Rhodamine Pink Rose Bengal . Phloxine	,, ,, Reddish Violets
Purplish Reds .	,, ,, rich Blue Violets

The brightest and most dazzling of colours, such as the rhodamine and eosine pinks, which readily fatigue the eye, are transformed, under the green-tinted medium, into beautiful shades of blue-violet, that can be examined leisurely for any length of time. On dyed pattern plate 1, in Appendix, are four bright colours, which, if the dyer examines them through a suitable film, will illustrate the effect.

No. 1 is changed to a brown, 2 into a soft violet, 3 into a dull maroon, and 4 into a soft old gold or cinnamon shade.

As we have already stated, in § 26, the most luminous part of the spectrum is that extending from scarlet and orange, through the yellow to the yellow-green. If, therefore, we have a coloured film, or glass, which absorbs this bright portion of the spectrum, we will have a suitable medium for examining all highly luminous colours.

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[1] For the absorption spectrum of this green film see Fig. 16 (B)

The writer finds that gelatine films, coloured with a solution of the blue-green dyestuff, technically known as China or Malachite green (tetra methyl diamido-triphenyl carbinol oxalate), admirably suits these requirements.

By examining the absorption spectrum of this dyestuff, as shown in (B), Fig. 16, it will be observed that it absorbs the most luminous parts of the spectrum, ranging from cherry-red, orange, yellow and yellow-green. It transmits a little extreme red, and all the green, blue and violet rays.

Such a tinted medium will be found of much service to the colour-matcher when making a careful examination of his bright pinks, reds, yellows and oranges.

§ 31. *Simultaneous Contrast* of colour is another interesting phenomenon requiring the attention of the colour-matcher. Shades may appear considerably altered in hue if they are placed in close juxtaposition to another colour, especially if that colour be a bright and decided one. It has already been observed, in § 10, that, after viewing for some time a luminous colour like bright red, the retinal nerve fibrils sensitive to red become exhausted and inactive, while the other two colour nerve fibres, *i.e.*, the green and the violet, act together and produce the sensation of seeing a complementary-coloured, or blue after-image. In the same manner, if a small piece of white paper be placed in the middle of a bright red or scarlet coloured ground, the white paper assumes a bluish aspect. If the ground be of a bright rhodamine-pink, the paper will assume a green tinge. If a green coloured thread be placed upon the same pink ground, the green will appear of a much purer and brighter hue, while if the same green thread be placed upon an orange ground, it will assume more of a bluish-green hue.

Again, if a carpet or calico print pattern consists of a series of black spots upon a bright green ground, the black will appear to the eye of a reddish or rusty hue, and not a pure black; but if the ground be a red one, the black will assume a bluish-black appearance. Such differences or peculiarities are greatly intensified if the coloured materials be strongly illuminated.

It may readily be observed, therefore, that the colourist who matches his shades in close proximity to bright colours, will often experience some difficulty in getting the exact shade desired. They must be slightly altered, more or less according to the influence of colour contrast exerted by the bright colour in juxtaposition.

It was phenomena like these that gave rise to complaints and difficulties in the selection of the right shades for some of the famous Gobelins tapestries in the royal manufactories of France. Complaints in regard to certain colours had been made, and the matter was brought under the notice of the eminent French colour-chemist, M. E. Chevreul, who was then director of the dyeing department. In his valuable work on the *Principles of the Harmony and Contrast of Colours*, he tells us that "while he was endeavouring to discover the cause of the complaints of certain pigments prepared in the dyeing laboratory of the Gobelins, he soon satisfied himself that if the complaints of the want of permanence in the light blues, violets, greys and browns were well founded, there were others, particularly those of

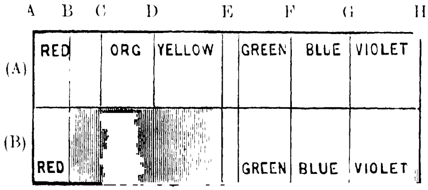

FIG. 16

(A) Solar spectrum.

(B) Spectrum of a gelatine film dyed with China green, showing absorption of the luminous colours of the spectrum, *i.e.*, from scarlet and orange to yellow-green. Hence its use as a medium for examining bright colours. (See § 30.)

the want of vigour in the blacks employed in making shades in blue and violet draperies, which had no foundation; for, after procuring black-dyed wools from the most celebrated French and other workshops—and perceiving that they had no superiority over those dyed at the Gobelins—he saw that the want of vigour complained of in the blacks was owing to the *colour next to them*, and was due to the phenomena of *contrast of colours*".[1]

Chevreul then saw that, to fulfil the duties of director of the dyeing department of the Gobelins, two quite distinct departments claimed his attention—one the chemistry of dyeing, and the other the study of the modifications of colour due—as he has since taught us—to the law of contrast.

§ 32. A colour may appear rich and saturated in one pattern, and yet appear dull and wanting in vigour when put into another pattern with a different scheme of colouring. Dyers and colour-matchers have often learned from experience that their colour recipes require to be slightly modified to suit different coloured patterns. Some of the colour ingredients have to be increased, or diminished, in order to adjust the shade to its required aspect, if it is to be placed in juxtaposition to some bright or decided colour in the pattern.

Chevreul gives us an instance of this, which is, no doubt, a common experience with every practical colour-matcher. A printing firm had a very good recipe for making a bright green, which was always found to be successful until, in one pattern, it appeared considerably yellower and wanting in green. It was found, however, that the poverty was due, not to the green colour itself, but to the influence of a blue ground on which it was printed. The blue, by effect of contrast, tended to make the green yellowish in appearance, and it was only after an increased portion of blue was added to the green to counteract this effect that the green assumed its usual beauty.

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[1] See preface to Chevreul's *Principles of the Harmony and Contrast of Colours*.

In matching textiles in which there are a number of bright and decided colours in juxtaposition, it is advisable to draw out a few of the coloured threads of the fabrics, so that they may be isolated from the influence of simultaneous contrast. A more successful match can thereby be obtained. If threads cannot be removed from the fabric, then the colour-matcher will find much help by employing small grey-tinted masks such as represented in Fig. 17, or pieces of neutral grey paper having a small hole in the centre. One of these can be placed on the textile fabric over the colour which is to be matched, and the observer sees only the necessary colour surrounded by the neutral grey of the mask.

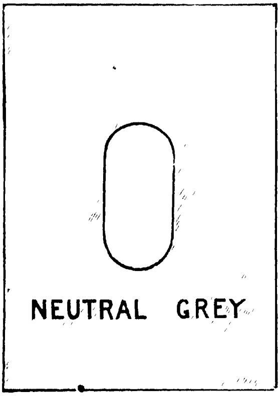

FIG. 17.—Grey mask for isolating colours when matching on brightly dyed fabrics.

By this simple device the colour under examination is freed from any surrounding influences of contrast. The masks may be tinted light grey, mid, or deep grey as desired. In matching dull or sombre-coloured fabrics, where all the shades in juxtaposition are of a subdued tertiary nature, such precautions are unnecessary, as the shades, being all dull, do not give rise to any contrast effects.

Several colourists have investigated the effects of simultaneous contrast, or this mutual influence which contiguous colours exert upon one another, and the results, obtained with the more important fundamental hues, are given in the following table.

It is worthy of note that all these results agree perfectly with the Young-Helmholtz, or red, green and violet, theory of colour. (See § 9.)

	Colours in juxtaposition.	*Change due to contrast.*
1.	Red	inclines to be purplish
	Orange	„ „ yellowish
2.	Red	„ „ purplish.
	Yellow	„ „ greenish.
3.	Red	„ „ brilliant
	Blue-green	„ „ brilliant.
4.	Red	„ „ orange-red
	Blue	„ „ greenish
5.	Red	„ „ orange-red.
	Violet	„ „ bluish.
6.	Orange	„ „ orange-red
	Yellow	„ „ greenish-yellow.
7.	Orange	„ „ red-orange.
	Green	„ „ bluish-green.
8.	Orange	„ „ brilliant.
	Cyan-blue	„ „ brilliant.
9.	Orange	„ „ yellowish.
	Violet	„ „ bluish.
10.	Yellow	„ „ orange-yellow.
	Green	„ „ bluish-green.
11.	Yellow	„ „ orange-yellow.
	Cyan-blue	„ „ blue.
12.	Yellow	„ „ brilliant
	Ultramarine blue	„ „ brilliant.
13.	Green	„ „ yellowish-green.
	Blue	„ „ purplish.
14.	Green	„ „ yellowish-green.
	Violet	„ „ purplish.
15.	Greenish-yellow	„ „ brilliant.
	Violet	„ „ brilliant.
16.	Blue	„ „ greenish.
	Violet	„ „ purplish.

Bearing such facts in mind, we can understand the danger of having in a standard pattern, or swatch book, a miscellaneous collection of shades in juxtaposition with each other; drabs side by side with greens, pinks beside blues, or olives beside reds. It would be well-nigh impossible to get a good match of any soft shade which was in close contact with a bright, luminous colour.

Swatch books, therefore, should be so arranged as to have all the colours classed together—drabs, olives, reds, yellows, greens, etc., all by themselves—and in this way the deceptive effects of colour contrast are avoided. In matching certain shades in colour compositions where the colours cannot be separated, the neutral tinted mask, as already described, will prove useful.

CHAPTER IV.

EXAMINATION OF COLOURS BY REFLECTED AND TRANSMITTED LIGHTS—EFFECT OF LUSTRE AND TRANSPARENCY OF FIBRES—OPTICAL NATURE OF DYESTUFFS—COLOUR-MODIFYING INFLUENCES IN DYED TEXTILES.

§ 33. The colours of dyed yarns and fabrics are generally examined by two methods, namely, by *reflected* and by *transmitted* light. Ordinarily we see all coloured objects by reflected light. The coloured rays, reflected from the surface of the material, are received by the eye in looking upon it.

By the *transmitted* light method, the dyed material is held up towards the light on a level with the eye, and in such a manner that the observer sees the coloured light transmitted through the surface fibres of the material.

This latter method is specially useful when the shades are dark and strong in tone, such as deep navy blues, blacks, maroons, deep olives, clarets, browns, etc.

As these two methods are being continually employed and referred to by every colourist, it may be well to give them more than a passing notice.

REFLECTED LIGHT EXAMINATION.

In Fig. 18 we have an illustration of an experienced colour-chemist in the laboratory matching his shades by the ordinary "reflected light" method. The rays of light strike straight down upon the dyed material; a certain portion is reflected unchanged from the outer surface of the fibres, while the remainder enters into the fibre, and there becomes decomposed by the dyestuff into coloured light. The light, after penetrating to a certain depth within the dyed fibre, is reflected back, and is received by the eye as coloured light.

Fig. 18.—Colourist matching by reflected light.

Indeed, in the examination of dyed textiles, the coloured fibres act in a manner analogous to dye solutions.

The fibres are all more or less transparent, and hold the dyes within them as it were in a state of solid solution.

The light, which strikes upon a piece of woollen cloth dyed scarlet, penetrates to a certain depth within the fibre of the wool, and is there deprived, by the peculiar and characteristic action of the dyestuff, of its yellow, green, blue and violet constituents.

After undergoing this process of *absorption*, the light is reflected out of the fibre, no longer white light, but white, minus its yellow, green, blue and violet rays; which leaves only the red and orange or scarlet to be reflected to the eye: hence the origin of the scarlet colour.

In this manner the light reflected to the eye, after penetrating to a certain depth of the coloured fibres, is similar to that obtained by passing the same light through a glass containing a solution of the dyestuff.

It must often be observed, however, in viewing the solution of a dyestuff, say, for example, Eosine pink or Rhodamine, that, if a very shallow or dilute solution be viewed, the pink becomes decidedly bluer, while if the depth or strength of the solution be increased, the hue of the colour becomes much redder, approaching more to a scarlet.

§ 34 This same phenomenon (which we shall consider under dichroism, § 41) is observed when such dyestuffs are dyed upon a transparent fibre with a good lustre, like wool or silk, and compared with the same colour dyed upon a less transparent and lustreless fibre like cotton or linen.

An eosine pink is always redder on wool or silk than on cotton, because the light can penetrate to a greater depth in a transparent fibre like silk or wool than in the more or less opaque fibre like cotton. In viewing by the ordinary reflected light method an eosine pink dyed on wool and on cotton, it will be observed that the cotton dye is bluer in hue than the one on wool, because the light in the former fibre cannot enter to any great depth, and becomes reflected with a bluish hue similar to a shallow solution of the dye; while the wool, being more transparent, allows the light to penetrate to a greater depth, and, therefore, when it is reflected it assumes more of a red hue, having had its bluer rays absorbed in its further passage through the dyed fibre.[1] In this manner it resembles a greater depth of the dye solution.

As the lustre and transparency of a fibre affect, to a great degree, the aspect of the dyed colour, and increases the difficulties in colour-matching, they will be considered specially (see §§ 37, 38).

§ 35 **Transmitted Light Examination.** This method, which is sometimes termed "overhand" matching, is very serviceable for showing to the colourist distinctions in hue which are imperceptible in the ordinary reflected light, or "underhand," method In examining the darker shades of maroons, puce, claret, browns, navy blues, deep sage-greens, blacks, etc, this method is indeed indispensable The two dyed specimens under examination are held up to the light, and the eye, in viewing along the surface of the material, sees only the coloured light, which is transmitted through the fibres on the surface, as shown in Figs. 19 and 20 In this manner the slightest variations in the hue of the very deepest shades can readily be observed, which it would be impossible to detect by simply looking down and viewing the materials from above.

In Fig. 19 the dyed swatches are put over the finger, and the eye of the colourist at (A) catches the beam of light (B) which is transmitted across the dyed fibres. In Fig. 20 we see the practical colourist holding up to the light his finger, over which are the shades he is matching, as in Fig. 19

The dyed colours also assume a richness, more resembling stained-glass, which cannot be obtained by the reflected light. This richness and saturation of hue is owing to the absence of the usual white light, which is always present in reflected light colours, and is, therefore, identical in nature to the unsurpassed richness of colour observed in viewing stained-glass, transparent paintings, or coloured films In all dyed fabrics there is reflected to the eye, along with the coloured light, a large proportion of unchanged white light from the surface of the fibres of the material, and this white light, combining with the coloured light, gives an impoverished and poorer look to the colours.

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[1] This effect is also increased by the fluorescence of such dyes as the Eosines. (See page 63)

A simple example of this may be observed in the beautifully rich green light which is transmitted through the green leaves of a tree when the sun is shining through them. But when the same leaves are viewed by reflected light, *i.e.*, viewed on the surface, the green looks dull and dead in comparison to its transmitted light colour.

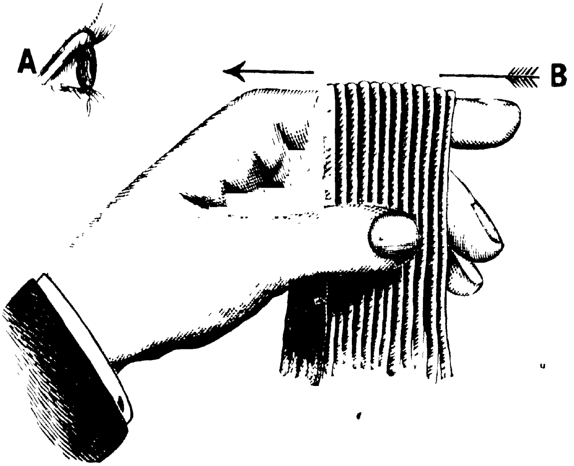

FIG. 19.—Diagram illustrating "overhand" or transmitted light method of examining dyed materials (A) Eye of observer (B) Direction of light.

The surface of the leaf reflects much white light, which impairs the richness of its green colour, and gives to it a more or less chalky appearance. If the surface of the leaf be covered with a growth of minute transparent hairs it will reflect more white light, and present a silken aspect with only a faint tinge of the green.

In the same manner, rough surfaced fibres, which scatter the incident light in all directions, never dye so rich and saturated colours as those transparent and lustred fibres which transmit a certain amount of light.

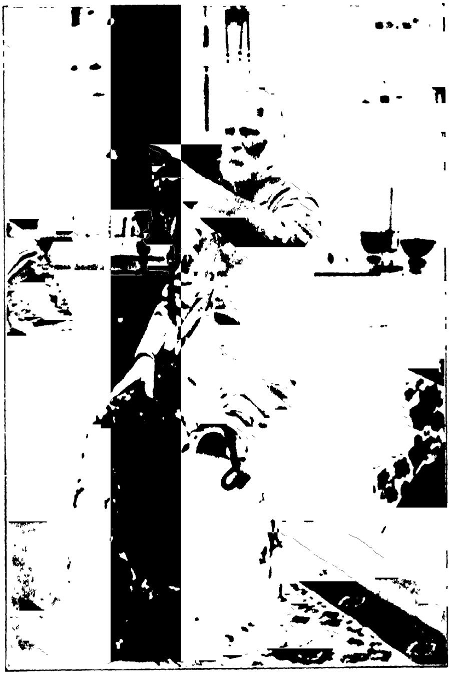

Fig. 20.—Colourist matching by "overhand" method

§ 36. An important feature in regard to matching by the transmitted light method is the fact that the experienced textile colourist can often tell whether a shade is dyed with natural colour stuffs or the aniline dyes.

For example, the natural colouring matters such as archil, fustic, quercitron bark and others all appear duller and a trifle redder, on viewing overhand, when compared with similar hues dyed with the aniline derivatives, which have a clearer and brighter hue when so examined. This is especially noticeable in shades of olive made with bark-yellow and indigo-blue when compared with shades matching them closely and dyed with aniline orange and perhaps wool green, cyanine-blue or aniline grey.

An interesting example of this was observed in two shades of reddish terra-cotta matching each other closely on looking down upon them One was dyed with fustic, azo carmine pink and a little aniline grey; and the other was produced with patent fustine (a brownish-yellow dyestuff) in place of the fustic. Though the two shades were quite similar by reflected light, or "underhand," they were found to show a considerable difference in hue by the "overhand" examination. The shade dyed with fustic showed a very decidedly yellower aspect by transmitted light than the one dyed with patent fustine, which preserved an appearance similar to its underhand colour Numerous examples might be given to show how the transmitted light method of examination may reveal certain little optical peculiarities possessed by the dyestuffs employed.

As a rule, the benzidine or diamine dyestuffs give shades which look normal by transmitted light, but dyes which possess any striking optical properties, such as fluorescence or dichroism (see §§ 11, 12), appear slightly altered in hue by looking through their surface fibres by transmitted light. For instance, a bright eosine, which is strongly fluorescent, shows a more orange or yellower aspect when viewed by reflected light than by overhand

This is owing to the orange hue of its fluorescence showing itself, and mingling with the reflected light colour; while, by viewing overhand, the transmitted light contains none of its fluorescent colour; hence the observer sees, in this way, the bluish hue of the eosine.

In a similar manner, dyers must have observed that in matching a dichroic colour like methyl-violet 3B, its lighter tints appear somewhat bluer by overhand than by viewing down upon them. The light, which is reflected from the dyed material, has entered to a considerable depth within the fibres, and, in doing so, has become robbed of more of its blue and violet rays, which produces an increased redness of hue in the coloured light so reflected. If the dyed material be of a velvet or cut pile surface, this selective absorption of the blue and violet rays is increased by the repeated reflections within the interstices of the fibres, and a much redder hue is produced. In viewing the dyed material by *overhand* or transmitted light, this phenomenon of selective absorption does not come into play, and hence its overhand aspect is slightly bluer than when looking straight down upon it.

Such phenomena are better observed when comparing a colour dyed on a plain surface with that of a cut pile or velvet surfaced fabric (see § 39), as the repeated reflections within a velvet pile give rise to dichroism.

In a similar manner, a tint of yellow buff, dyed with fustic extract and a cochineal pink, looks much redder by reflected light, on a velvet pile, than by overhand, owing to the action of selective absorption occurring within the depths of the dyed fibres.

It is impossible to get a colour, either a yellow, citrine, russet or olive, having fustic as the yellow constituent, to match by "overhand" similar colours dyed with the aid of aniline yellows.

Shades produced with fustic have always a peculiarly greenish flat hue by transmitted light, which contrasts strangely with the rich clear yellow tone of similar shades having an aniline yellow like naphthol yellow as a constituent.

In this way—and many other examples might be given—the transmitted light method of examining colours may prove of great help to the dyer, by revealing to a certain extent the optical nature of the dyes employed.

Overhand matching is certainly the best way to examine dyed shades, as the slightest differences which would otherwise escape detection can be readily observed.

In some classes of textile work it is often desired to have the dyed shades as dull and "thin" as possible, producing what we might almost term a *washed-out-like* aspect. This is sometimes done to give an antique appearance to certain fabrics—imitation of old tapestries, for example.

Other classes of work require as full and rich tones of colour as the dyer can produce, and, in order to reach results so diverse in their nature, the colourist must select, with great care, the dyestuffs to be employed.

After long experience the observant dyer can tell the behaviour and properties of most of his colouring matters, and knows which are the best to employ under the circumstances.

CHAPTER V.

COLOUR-MODIFYING INFLUENCES IN DYED TEXTILES—LUSTRE AND TRANSPARENCY OF FIBRES—VELVET PILE SURFACE—OPTICAL PROPERTIES OF DYES—DICHROISM—FLUORESCENCE.

§ 37. The matching of shades, either on the painter's palette or on dyed fabrics, is always a painstaking and delicate task; but the difficulty of matching on textiles is, to a large extent, increased by certain modifying causes which come into play in the dyed fabric. These are unknown to the painter and paperstainer. All textile colour-printers and dyers must have observed the slight changes in the aspect of the shades when dyed on fibres or fabrics of different natures. These modifications of hue are produced principally by the optical structure of the fibre itself, or the woven fabric, and by the optical properties of the dyestuffs employed.

The modifying influences at work in the matching of textiles may be divided into three classes, *i.e.*—

1. The optical properties of the dyed fibre = *viz.*, lustre and transparency.
2. Structure of the woven textile fabric = *viz.*, plain or velvet pile surface.
3. Optical properties of the dyestuffs = *viz.*, dichroism and fluorescence.

§ 38. Colours dyed on a fibre of good lustre and transparency, such as silk, Ramie, or China grass fibre, and the finer qualities of wool, give a richness and depth of shade which cannot be equalled in fibres of a less lustrous nature. *The greater the lustre and transparency of the dyed fibre, the more difficult it is to match perfectly.* Thus, dyed cotton, linen and jute are more easily matched than wool, and dyed wool, again, is easier matched than dyed silk. Indeed, silk and China grass, or the Ramie fibre, which has a splendid silk-like lustre, are most difficult fibres to match perfectly, as their great transparency and lustre give full play to the optical peculiarities of the colouring matters with which they are dyed.

Such coloured fibres are also more liable to undergo changes in hue under the artificial lights. Dyed cotton or linen, on the other hand, being more opaque fibres, resemble the pigment colours, and do not show any abnormal changes in hue under gaslight.

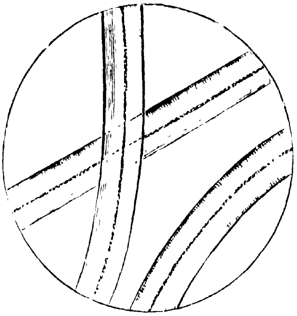

FIG. 21.—Microscopical appearance of silk fibre.

The property of *lustre*, or of reflecting light, possessed by the various textile fibres bears an important relationship to their physical structure. The smoother and more cylindrical the outward aspect of the fibre is, the greater will be its lustre.

Thus, for example, if we take three fibres differing in degrees of lustre, like silk, wool and cotton, and examine them under the microscope, it will be observed that the silk has a smooth, shining surface like a rod of glass. The wool is not so smooth as the silk. It possesses a more uneven surface, and is therefore less lustrous; while the cotton is still more uneven, and shows a rough, twisted fibre, which scatters the light in all directions, and is therefore devoid of any lustre.

These characteristics of the different fibres, as seen under the microscope, are illustrated in Figs 21, 22, 23 and 24.

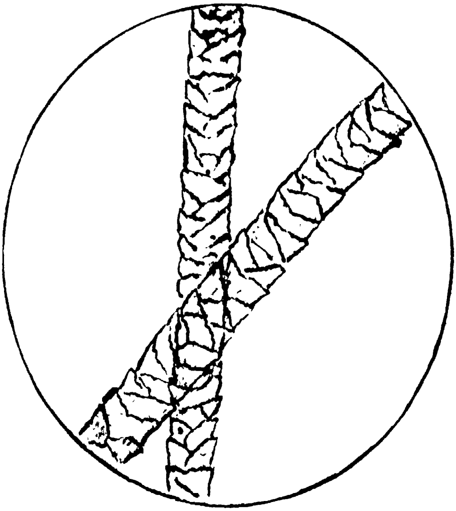

FIG. 22—Wool fibre under microscope

It will be observed that the smooth surface of the silk fibre, Fig. 21, enables it to form threads all closely parallel to each other, thus producing a surface having a high reflecting power or lustre.

The high lustre of the China grass, or the Rhea or Ramie fibre, is also explained in the same manner, as, from a microscopical examination, it is found to show a very smooth, glass-rod-like structure, represented in Fig. 24.[1]

The serrated edges of the scales present in the wool fibre, as shown in Fig. 22, lessen its lustre, by breaking the continuity of its reflecting surface. Hence, a wool having its epithelial scales prominently developed, such as merino, is termed a non-lustred wool; while those having the scales lying closer and firmer to the stem, and thus presenting a smoother and more highly reflecting surface, such as the alpaca and mohair fibres, are termed lustre wools.

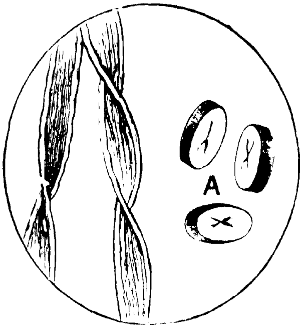

FIG. 23.—Cotton fibre under microscope. (A) Mercerised.

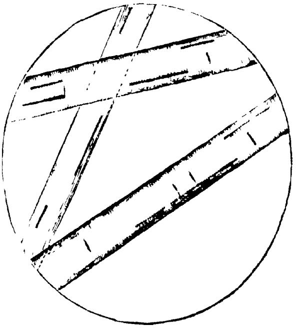

FIG. 24.—China grass, or Ramie fibre, under microscope

Cotton, as will be observed in Fig. 23, consists of a flattened and twisted tube-like fibre, which reflects the incident light, not in any definite direction, but scattered in all directions, thereby reducing the property of lustre. But if the cotton fibre be mercerised, *i.e.*, treated with a solution of caustic soda, it shrinks up, and assumes a more cylindrical form resembling silk, shown as (A) in Fig. 23. Hence we find that mercerised cotton possesses more lustre than ordinary cotton, as it approaches more to silk, or Ramie fibre, in its physical structure.

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[1] Drawn from photo-micro prepared by J. M. Arnot, F.C.S.

It is well to remember that the more nearly cylindrical the structure of the fibre is, the more lustrous it becomes. The fibres of jute and linen have a little more lustre than cotton because they are smoother, and more equal in formation, and thereby are better adapted to reflect the light.

Lustre and transparency of fibre accentuate the optical properties of the dyes. Thus, the beautiful pink dyestuffs, rhodamine and eosine, when dyed on silk, have a more orange hue than when dyed on cotton, owing to the orange fluorescence exhibited by these dyes being apparent on the lustrous silk, and absent on the lustreless cotton. The hue of the pink on the cotton, therefore, is somewhat bluer, or less orangy, from the absence of this fluorescent light.

Many similar examples, more or less striking, must have come under the notice of every observant practical dyer.

The subject of matching accurately dyed fibres having different lustres and degrees of transparency, and fibres of different texture, forms the most difficult task that the dyer and textile colour-chemist have to contend with.

Indeed, the same dyestuff when dyed on one fabric may appear a somewhat different colour when dyed on another fabric of different texture. To make a perfect colour match on fabrics of similar nature, the colourist must endeavour, as much as possible, to employ dyestuffs having similar optical properties to those employed in dyeing the original shade required to be matched. Sometimes, where an absolutely perfect match is required, the colour-chemist is often at a loss to obtain some particular aspect present in the original fabric, and he is then the better of the opinion and advice of others.

In Fig. 25 we have a snapshot of a colour-matching laboratory, where an experienced colourist is giving some hints on a difficult point to his assistant (see also §§ 33 and 47). They are comparing the swatch with the fabric to be matched.

It is, we might say, almost impossible to produce in every respect a *perfect* match with some colouring matters dyed on different fibres like wool and cotton, or cotton and silk.

Though they may appear identical to the unaided eye, they may present a dissimilarity when examined in gaslight, or when viewed through tinted glasses. For example, methyl-violet (3B) when dyed on cotton is exactly the same hue as when dyed upon wool. In daylight, if the two be compared side by side, they seem identical, yet, when both are viewed in gaslight, the wool looks considerably *redder* than the cotton. This is owing, as we have already stated in § 34, to the more transparent nature of the wool fibre, which permits of the phenomenon of selective absorption taking place within the fibres. The light becomes more saturated with red rays during its brief passage within the dyed fibre, and this effect

FIG. 25.—"A difficult point." View in colour-matching laboratory.

is considerably increased in an orange light, such as gaslight, where the red and yellow rays are in excess of the blue and violet. This property of selective absorption or dichroism is considered specially in § 41.

§ 39. In making a careful match of dyed fabrics, the colourist will experience much difficulty with certain colours dyed upon a velvet surfaced or cut pile fabric. Here the phenomenon of selective absorption shows itself, produced by the repeated reflections of the coloured light within the interstices of the cut pile. A velvet pile fabric is generally the most difficult of materials to match satisfactorily, as the optical properties of the dyestuffs, especially *dichroism* (see § 41), become more apparent. The light, instead of being reflected from the inside of the fibre, as in the ordinary cases of plain surfaced materials, enters to a considerable depth within the interstices of the velvet or cut pile, and in so doing becomes more and more enriched and saturated with coloured light, as if it were passing through a solution of the dyestuff. While doing so, the coloured light undergoes the process of selective absorption, *i.e.*, certain coloured rays become more and more absorbed, until the light is reflected out of the depths of the fibres, generally of a hue different from its surface colour. The nearer any dyed fibre or fabric approaches, in its optical nature, to that of a dye solution, the greater will be its liability to change in hue when woven into a velvet fabric, and the more liable will the shades be to alter under artificial lights.

The deepening and enriching of the colour by the repeated reflections among the fibres tends more and more to modify the original hue of the dyestuff, as the resulting hue is produced by the sum of those rays which traverse the most freely through the colouring matter.

Methyl-violet, for instance, looks somewhat redder and more of a plum colour, when dyed upon a velvet surface, than when on a plain surfaced fabric like calico. Many dyestuffs show this property in a very marked degree. For example, a class of shades can be dyed with naphthol-yellow and methyl-violet, which are of a moss green shade on plain surfaced goods, and appear of a *bronzy brown* shade when cut into a velvet pile. During the repeated reflections, which the light undergoes within the interstices of the velvet, the green light becomes gradually absorbed, and this produces a corresponding predominance of the red and orange rays, giving to the velvet fabric a much browner aspect. It will be found, also, that dichroic colouring matters, having a tendency to transmit the red and orange rays more freely than the blue and violet, become abnormally red in gaslight. This may be observed in methyl-violet, and also in the moss green compound shades which we have just cited. The violet changes to a magenta hue, and the moss greens become red browns and plum shades. As another example, we may mention two buffs, one dyed with fustic and a cochineal red, while the other, matching it exactly, is dyed with an aniline yellow, with a touch of rhodamine pink. On plain surfaced materials, these buffs are of a yellowish hue, but when cut into a velvet pile they both become much redder, owing to dichroism of their constituent colouring matters. They also become exceptionally red in gaslight.

When dyers are matching colours on a velvet pile surface, it is necessary to cut the trial swatches so as to form a pile similar to the velvet. By doing so a more correct judgment is obtained, because many dyed yarns appear to match well while in the hank state, and yet show a considerable dissimilarity when viewed in the velvet surface.

§ 40. **Optical Properties of the Dyestuffs.**—Textile colourists, and especially *silk dyers*, often experience great difficulty in the matching of their shades. This generally arises from the optical nature of the dyes in combination with a high lustred fibre, and is experienced more in bright sunny weather, when the quality of the daylight is apt to be variable. It is often found, for example, that two shades, which have been carefully matched in the open air, present a slight difference, and are no longer good matches, when examined indoors.

Indeed, several tertiary or compound shades have been observed by the writer to change in their aspect *several times during the course of the day*, and when such is the case, it may be easily understood how difficult it is to match perfectly with dyes which change so readily in their appearance.

We have already fully considered some of these modifying causes, *i.e.*, the quality of the daylight, and the optical peculiarities of the dyed fibres or fabrics, and have now to give our attention to two optical properties sometimes possessed by the dyestuffs themselves, namely, *dichroism* and *fluorescence*, which are of considerable importance in the matching of shades.

§ 41. *Dichroism.* This interesting property is possessed by most colouring matters, and is of special interest and importance to the dyer, the colour-mixer and matcher. Most dye solutions undergo a slight change in hue when reduced, or diluted, from their deep tones into their lighter tints, and many coloured "stuffs" exhibit this phenomenon in a very marked degree. A beautiful, but now obsolete dyestuff, quinoline blue, changes from a pure *blue* in a thin or dilute solution to a *red* in a deep or strong solution.

Most dyers will have observed how methyl-violet and malachite, or China green, and many aniline blues, become very much redder in tone the deeper or stronger the dye solution is made. They gradually lose, as the depth increases, the green and blue rays which are observable in their thinner layers.

In examining the dichroic properties of dyestuffs, a hollow glass prism or wedge is used, into which the dye solution is introduced. By viewing through the thin end of the wedge, or through one of the angles of the prism, the colour of the dyestuff in its thinnest layer can be noted; while the colour transmitted through the increasing thicknesses of dye liquid can also be observed, and any exceptional change of hue, or dichroic property, is at once made apparent.

With such a piece of apparatus it is found that magenta changes from a blue-pink in dilute solution, or thin layer, to a cherry-red in strong or deep solution, and—

Picric Acid	changes	from a	Greenish-yellow	to a	pure Yellow.
China Green	,,	,,	Blue green	,,	Violet-blue.
Malachite Green	,,	,,	Blue green	,,	Red-purple
Methyl Violet	,,	,,	Blue violet	,,	Claret-red.
Bichromate of Potash	,,	,,	Yellow	,,	deep Orange.
Chromic Chloride	,,	,,	Green	,,	ruddy Brown.
Prussian Blue	,,	,,	Seagreen-blue	,,	deep Blue
Quinoline Blue	,,	,,	clear Blue	,,	fine Red.
China Green and drop H Cl		,,	Yellow-green	,,	Claret red.
Litmus	,,	,,	Blue	,,	Red-purple
Acid Indigo Extract	,,	,,	Greenish blue	,,	Purple-blue

In all such examples as we have given certain coloured rays become *absorbed*, or quenched, during their passage through the deeper layers of the dye solution. As the rays become absorbed, the other coloured rays predominate, and hence the resulting hue of a deep dye solution is produced only by those coloured rays which traverse the most freely through the solution, or, as it were, have survived in passing through the solution. This is what is generally termed "selective absorption," as the dyestuff *selects* certain coloured rays from among the others, and quenches or absorbs them during their passage through the colour liquid or dyed fibre.

The same dichroic effects present in dye solutions are observable when the colours are dyed upon transparent fibres of good lustre and woven into velvet or cut pile fabrics. This is the reason why certain dyed colours alter considerably in hue when dyed on fabrics having a rich velvet pile, as compared with the same dyestuff on fabrics having a "terry" or uncut pile, and also on plain surfaced goods such as calico, tapestry or woollen cloth material

We have already observed, in §§ 38, 39, that dichroism becomes apparent in dyed fabrics only when the fibre possesses a sufficient degree of transparency and lustre.

It is this same property of dichroism that gives rise to the slight changes of hue in a colour when it is reduced, either with water, printing paste, or with white, to form a gradating scale, or series of tints. Reds, for example, when reduced to form tints of red or pinks, may go off into an orange or buffy hue. Blues, likewise, may go greenish or reddish when diluted into tints. All ordinary colours and dyestuffs, as a rule, show some slight modification in hue on reduction into light tints, but there are others which show it to such an extent as to be highly objectionable to the textile colourist. The behaviour of a colour on dilution is a question of much importance, as it often determines whether a colour is serviceable or not for mixing with others to get a desired result.

Two yellows, for example, in their strong tones either dyed upon wool, or in concentrated solutions, may appear identical to the eye, but when mixed with a certain proportion of blue to produce a green, the results obtained may be totally different.

One yellow may give a fairly pure green, while the other may give a "broken" green, or olive, on admixture with blue. Such results are rather disappointing to the colourist, but the explanation may be found by reducing the two yellows into a series of tints, and it will be found that the yellow which gave the dull, broken green on admixture with blue, will reduce out into a buffy or orange tint instead of a pure lemon yellow like the other.

The careful colourist, when testing the capabilities and mixing properties of his dyes, always reduces them into a gradating scale of tints to see how they behave on dilution. On doing so it is often found that the colour does not reduce well. It does not give an equally balanced and harmonious chromatic scale, and may require the slight addition of another dyestuff to keep the series in a proper step of gradation.

Dichroic colours dyed upon fabrics are most difficult to match accurately, as they are not only sensitive to the slightest change in the quality of the daylight, but, as already said, the difference in hue between their aspect on a velvet surface and on a plain surface is very marked.

Many examples might be given, but we will confine ourselves to one instance. A class of flat olives and moss greens can be made by dyeing with fustic, or naphthol-yellow, and methyl-violet (3 B). Such colours, in their lighter tints, have a green sage aspect in plain surfaced material, while on a rich velvet pile fabric they assume a reddish-bronze hue, greatly different from their former colour. Such shades, also, do not reduce well into a scale, as their deeper tones become far too purply-red to step well with their much greener tints.

The repeated reflections which the light undergoes during its passage within the interstices of the velvet pile fabric give rise to the process of selective absorption, in the same manner as the deepening of the dye solution already considered.

§ 42 *Fluorescence*. The optical property known as fluorescence is observed in great beauty in many of the aniline dyestuffs, notably those of the derivatives of *Fluorescein*, an anhydride of resorcin phthalein. These dyestuffs comprise the beautiful Eosines, Rose Bengal, Rhodamine, Phloxine, etc.

Fluorescence is commonly observed in a solution of sulphate of quinine, or a piece of yellow "canary" glass coloured with the oxide of uranium. The former, though pure as water by transmitted light, shows a beautiful bluish-violet light when viewed by reflected light, and the latter appears a fine green when viewed in certain directions. An alkaline solution of fluorescein possesses an intense bright green fluorescence, which is still visible after being immensely diluted (1 part in 2,000,000 of water).

The yellow dyestuff, Uranin (a sodium salt of fluorescein), also exhibits this phenomenon in a remarkable degree. Strongly fluorescent colours, when dyed upon highly lustred fibres such as silk and Ramie or China grass, exhibit their fluorescence; but if the fibre be a lustreless one, like cotton or linen, where the rough surface of the fibre scatters the incident light, then this property is destroyed. This may readily be observed by comparing the hues of rhodamine dyed upon silk and upon cotton. The light reflected from the dyed silk is of a more orange cast than that of the dyed cotton, which appears bluish beside the silk. This is owing to the fluorescent orange-coloured light of rhodamine being reflected from the smooth and shining outer surface of the silk, while the dyed cotton, having no such power of surface reflection, is devoid of the orange-coloured rays. (See their microscopic appearance in Figs. 21-24, p. 62.)

In matching strongly fluorescent shades, some little peculiarities are observed which are worthy of notice. For example, a decided difference in hue is observed between their reflected light and transmitted light aspect. A peculiar tone of violet, or heliotrope, may be produced by dyeing with rhodamine, or any of the fluorescent eosine pinks, combined with any of the acid greens, like wool green.

On viewing the shades by reflected light, *i.e.*, looking down upon them, they are of a peculiarly *reddish* hue, and change in their aspect when held in various different directions. This reddish light is owing to the fluorescent property of the eosine pink.

If the shades be held up to the light and viewed "overhand," or if the threads of the swatch be held up and the light allowed to filter through them, it will be observed that the hue becomes decidedly bluer, approaching more to the appearance of the ordinary bluish methyl-violets. This difference in hue between the reflected and transmitted light aspects of the dyed colour is due to the presence of the orange fluorescent light visible in the former and reflected from the surfaces of the fibres. In viewing by transmitted light, the orange fluorescence is lost; hence the colour appears much bluer or less orange to the eye.

This effect may be still further accentuated by cutting the swatch so as to form a velvet pile surface, or a tuft, similar to plush. By doing so, the fluorescent light is seen to greater advantage, with the result that the cut or velvet surface end appears more orangy than the plain surface or uncut swatch.

Many similar examples might be given, and it is only by studying a few simple cases at first that all such phenomena can be satisfactorily explained. The truth of this explanation may be tested in a very simple manner by dyeing a tone of violet with a *non-fluorescent* dyestuff, to match exactly by *transmitted light* the violet made by combining eosine pink and an acid green. If, when a good match has been obtained, the two shades be then viewed by reflected light, *i.e.*, by looking down upon them, it will be observed that they are no longer matches. The non-fluorescent shade appears much bluer than the compound one, owing to its absence of orange fluorescent light.

CHAPTER VI.

USE OF TINTED FILMS IN COLOUR-MATCHING—COLOUR VISION—DEFECTS OF THE EYE YELLOWING OF THE LENS—COLOUR-BLINDNESS.

§ 43. **Use of Tinted Films in Colour Examination.**—It has already been observed, in § 30, Chapter III., that green-tinted glasses or coloured gelatine films can be employed with great advantage in matching and examining bright colours. As the most luminous part of the spectrum is the scarlet, orange, yellow and bright yellow-green, the bluish-green-tinted glass used for examination merely acts as an absorptive medium, and thereby reduces the dazzling luminosity of these hues into a more sombre class of shades, which can be viewed for any length of time without fatiguing the eye.

But properly selected glasses of different colours may be employed with the greatest advantage in the examination of not only luminous colours, but of all kinds of shades, even the most sombre. By the aid of tinted films, the colourist can obtain an insight into the optical properties and peculiarities of shades that he could not otherwise gain, unless after an exhaustive spectroscopic examination. The writer employs glasses, or gelatine films, coloured orange, yellow, green, red, cobalt blue and violet, in the study of colour phenomena, and finds their assistance invaluable for revealing, at a glance, any peculiarities of construction in the spectra of the shades under inspection. For example, we might have two bright hues of pink dyed upon wool or silk, one dyed with rhodamine and the other dyed with some of the strongly fluorescent dyestuffs like eosine and erythrosine. The two pinks may appear identical to the eye, but if they be viewed through a blue green glass, or film, similar to that mentioned in § 30, the two appear somewhat different.

We find differences in their appearance and optical behaviour that could not be detected with the unaided eye.

The rhodamine pink becomes a soft tone of violet, while the strongly fluorescent eosine pink appears much redder, and sometimes much lighter in tone than the other.

An example such as this has repeatedly come under my observation, and, so marked is the difference of behaviour in the apparently similar hues, that they need to be seen to be believed. With cobalt blue, orange and violet-tinted glasses most interesting and instructive results can be obtained on viewing many of the dyed materials. Olives, sages, drabs, old gold shades, and especially the soft mode shades, often present interesting examples for the investigation of the colourist.

Two shades of old gold, for example, one dyed with naphthol-yellow, orange and wool green, the other dyed with fustic, orange and methyl-violet, may present the appearance of an excellent match in daylight, and yet when they are examined through either the orange or the green films, they present a wide difference in appearance from each other. Under the orange film, the shade containing the wool green becomes very much greener, while the other, having the fustic and violet, becomes very much redder. Thus the one shade growing greener, and the other becoming redder, makes a very striking dissimilarity of hue between the two shades, which were evidently similar in the daylight when viewed without the intervention of the films.

This peculiar behaviour of the dyestuffs depends upon their absorption spectra, and the explanation of such modifications can be found only after a careful spectroscopic examination of the dyestuff itself (see Chapter IX.)

§ 44. **Orange Film.**—One of the most useful tinted mediums for such examinations is the **orange film**, *i.e.*, a piece gelatine film dyed to a suitable depth with an aniline orange. This is found most useful when the dyer wishes to determine the "gaslight aspect" of shades.

It is now becoming a question of considerable importance, when making an accurate match of any dyed material, to examine the colours in gas, or any artificial light, in order to see if they show any great changes in hue. Many dyes show such a difference in appearance under artificial illuminants as almost to exclude their use where careful matching is required.

In order to see, during the daytime, how any dyed material looks under gaslight, it is not necessary to take it into a room illuminated solely with gaslight. All that requires to be done is to examine the material through the orange-tinted film, when a very good idea of its gaslight aspect will be obtained.

Unless this care be taken, it may often be found that a fine series of "stepping" or gradating shades do not present such a satisfactory gradation when viewed under artificial light. This is specially noticeable when various members of the series are composed of different dyestuffs. (See Figs. 3 and 4 in frontispiece.) This interesting subject of colour appearances under the artificial illuminants is fully treated in subsequent chapters (see VII., VIII. and IX.).

§ 45. It may be interesting to mention that this method of investigation has lately been shown by a French scientist to yield valuable results at the museum in Paris in determining the composition of precious stones.[1]

The results, which have been communicated to the Academy of Sciences, are interesting, and show how spurious gems, though to the naked eye identical in appearance to genuine ones, can readily be detected.

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[1] M. Henry Cros in *Journal des Débats*, Paris, 1899.

For example, the genuine emerald when seen through properly tinted glasses assumes a purplish rose colour, while the imitation gem exhibits a green hue, due to the presence of its copper base. The genuine sapphire preserves its deep blue, while the false gem turns a rosy red, indicating the presence of a cobalt base.

The investigator gives a most interesting case where a small spherical cup of a sky-blue colour from ancient Egypt was examined through the coloured medium. The whole cup exhibited a blue colour, similar to that observed with the naked eye, with the exception of a small piece near the edge which assumed a *reddish* colour. This was owing to the small piece used in its restoration not being made with the same colour base as the original cup. While the blueness of the cup was due to copper, the small fragment inserted, though identical in colour, owed its blueness to a cobalt base. Hence the different behaviour and appearance when viewed through a properly coloured medium.

Similar examples of the different behaviour of colours, apparently identical to the unaided eye, are of every-day occurrence with the observant colour-matcher and dyer. This same method of research, *i.e.*, the employment of suitably coloured media, the present writer has applied for many years to dyed textiles.

§ 46. **Defects of the Eye.**—In the careful matching of colours, it is well to remember that every eye has not the same power of colour-perception, and many people who are very far from being what is termed "colour-blind" cannot distinguish the finer differences in hues which can be readily detected by the good colour-matcher. It has been proved, indeed, by Mr. Lovibond that there may be a considerable variation in the colour-perceptive power between the two eyes of the one person. If the one eye is normal and the other abnormal, it is rather difficult to discover the discrepancy, as the two visual images become blended upon the retina But, with a suitable apparatus, the images from both eyes may be kept separate, and thus any difference between the two colour-perceptions may be readily detected.[1]

§ 47. **Yellowing of the Lens**.—As the crystalline lens of the eye (see Chapter I., § 6) grows denser with age, it often acquires a yellowish tinge, which alters considerably the appreciation of the *blue* constituent in colours. In ordinary circumstances this yellowing of the lens through age would cause no inconvenience, but with colour-matchers and artists the case is very different. Liebreich has pointed out that the cold blueness to be observed in the later pictures of Turner and Mulready—the latter artist painted till he was over seventy years of age—was due to this yellow degeneration of the lenses of their eyes. In order to see the later works of these artists as they themselves would see them, with all their glow and warmth, it is necessary to view them through a yellowish-tinted glass, when they acquire the same rich scheme of colour as their earlier works.

It has been noted also that persons who have undergone an operation for cataract, after the yellowish lens has been removed, complain that everything in nature appears to them very blue. After a while, when the eye gets accustomed to the white light, this effect passes off

It may be observed that many dyers and colour-matchers who are well up in years are not so perfect matchers as they used to be. A gentleman known to the writer was a splendid colour-matcher some twenty years ago, and, from his published work at that time, he must have possessed abnormally good colour-perception. Now, however, and he is over seventy, he has informed me that he cannot make a satisfactory match with dyed fabrics, the yellowing of the lenses of the eye has become too pronounced.

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[1] See *Measurement of Light and Colour*, by J. W. Lovibond, F.R.M.S.

As a similar case in point I remember having some discussion with an old and experienced colourist, who was also an excellent colour-matcher, regarding the exact appearance of two differently composed shades of red buff, resembling a tint of a terra cotta.

Number one shade was dyed with azo-carmine, fustine and aniline grey, while the second shade was dyed with orange, rhodamine and 10 B violet.

To the eye of the older colourist these two shades appeared nearly identical, but, if anything, the *number one* shade, he said, was slightly *redder* in hue than the other. To my younger eye the appearances of the colours were exactly the reverse. The *second* shade, *i.e.*, that dyed with orange, rhodamine and violet 10 B, was decidedly *redder* than number one, which appeared considerably yellower.

For some time each held his own opinion as being the right and true one until, guessing it might be a case of the yellowing of the lenses in the eyes of the older colourist, I viewed the two shades through a piece of yellow-tinted gelatine film, when they presented at once an appearance exactly as the old gentleman had described, *i.e.*, the first shade, dyed with azo carmine, fustine and grey, was much redder than number two shade. The reason for this difference was due to the fact that the second shade, composed of orange, rhodamine and violet, was what may be termed a *super sensitive* shade, changing in aspect even with a slight variation in the quality of the daylight or the time of the day. Such shades are well known, and well disliked among dyers and colour-matchers. They alter greatly in appearances in artificial illumination, which always contains an excess of the yellow and orange rays. Shades of this nature likewise become considerably altered in aspect to those whose eye lenses are yellowed.

§ 18. **Colour-Blindness, or Dichromic Vision.** The normal human eye is capable of distinguishing three primary colours which, when mingled in varying proportions upon the retina (see § 5), produce all the infinite variety and beauty of colours to be found in nature. The spectrum as seen by normal colour vision is represented in Fig. 26, No. 1. Red, yellow and blue were formerly considered as the three primary colours, but, as we have observed in Chapter I, § 9, the true fundamental colour sensations are red, green and violet, according to the most approved theory of Young and Helmholtz. It must be remembered, however, that this red, green and violet theory has reference only to the mingling of coloured *lights* upon the retina and not to the mixing of *dyes* and *pigments*, for which the red, yellow and blue are the only practical primaries.

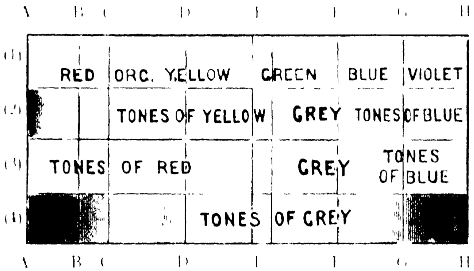

FIG. 26.—(1) Spectrum as it appears to normal "trichromic" vision. (2) "Red-blind" vision. (3) "Green-blind" vision. (4) Totally colour-blind.

Red Blindness. ¶ The commonest form of colour-blindness is where the sensation of seeing red is deficient. This "red blindness" is frequently termed "Daltonism," from the fact that the well-known chemist, Dr. John Dalton, was himself afflicted with it, and he was the first to carefully describe it in his first paper read to the Manchester Society in 1794.[1]

To the eye of a "red-blind" person the spectrum is shortened, and consists of only two colours, which they term yellow and blue. The extreme red of the spectrum is invisible, while orange, yellow and yellow-green are to them varying tones of yellow The greenish-blue of the spectrum appears a pale neutral grey (see No. 2, Fig 26). Beyond this all the rest of the spectrum from blue to violet appears varying tones of blue No 1, Fig 26, represents the full spectrum as seen by the normal trichromic vision; No 2 represents the spectrum as seen by a red-blind person. To persons afflicted with this, the commonest form of colour-blindness, there appears no difference in hue between scarlet poppies and green grass A dark red appears to them a black.

An instance is known to the writer where a gentleman, who, though well up in years, had never suspected any deficiency in his colour vision, was one day going to attend a funeral wearing a dark red necktie His friends remonstrated with him, but he maintained it was a pure black It is said likewise of Dalton, who was a strict Quaker, that he at one time wore in combination with his sombre grey dress a pair of deep red stockings, under the impression that they were of a quiet black

Green Blindness. Another and less common form of colour-blindness is where the green perception is wanting.

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[1] "Dalton saw no difference between red and green, so that he thought the face of a green laurel leaf a good match to a stick of red sealing-wax, and the back of the leaf answered to the lighter red of wafers When Professor Whewell asked him what he would compare his scarlet doctor's gown to, he pointed to the leaves of the trees around him Dalton found twenty persons possessed of the same peculiarity of vision as himself. The celebrated metaphysician, Professor Dougall Stewart, was one of them, and could not distinguish a crimson fruit from the leaves of the tree on which it grew, otherwise than by the difference in its form."—(Dr. George Wilson in his *Life and Discoveries of Dalton.*)

Only two colours are visible in the spectrum to such persons, and these they term red and blue, in varying tones (see No. 3, Fig. 26). What they call red extends from extreme red through the orange and yellow as far as the yellow-green Then where the normal eye sees blue-green and blue, the "green-blind" person sees only grey, and then blue extends from the blue down to the violet (as shown in No 3, Fig. 26)

To a "green-blind" person red and green both appear similar, i.e., red, while to the "red-blind" person red and green appear tones of yellow, as shown in No 2, Fig. 26 To both of them a red cherry or a scarlet poppy cannot be distinguished from the green leaves, except by their different forms. It is well to know, however, that colour-blind persons can be greatly assisted by viewing through suitably coloured glasses or gelatine films For example, "red blind" persons, by viewing through a green glass, can distinguish the difference between red and green, which they could not do otherwise With the green glass the red object becomes much *darker*, almost black in tone, while the green is unaffected, and thus the two are readily distinguished

For "green-blind" persons a piece of red glass or coloured film is required, which has the effect of making the *green* much darker, and thus separating it in appearance from the red. To a person who is *totally* colour-blind, i.e., can distinguish no colour whatever, everything is a dull, neutral grey. The "spectrum" of the vision of such a case is represented in No 4, Fig. 26 Fortunately, cases of absolute colour-blindness are very rare

It is rather remarkable that there are very few cases of "violet blindness".

§ 49 It is possible, by means of wearing red or green-coloured spectacles for a considerable time, to render oneself temporarily colour-blind to the red or the green, but it is an experiment the writer would not recommend to dyers and colour-matchers whose eyesight and powers of colour-perception are too precious to be tampered with.

Dr. Burch, however, has experimented upon himself in this direction, and gives us some interesting details of his seemingly rather rash investigations. He exposed the eye to 'the glare of bright sunlight, behind a sheet of ruby glass, in conjunction with a gelatine film dyed with magenta, and thus rendered himself "red blind".

Scarlet geraniums, he tells us, looked black, and red roses blue. Exposure to green extinguished all green and yellow, but left the length of the spectrum unchanged. The exposure to yellow or "yellow blindness" is particularly interesting, as it can be confined to certain portions of the retina, and the red, green and yellow were extinguished. This result would seem to prove the Young-Helmholtz theory that yellow consists of red and green rays combined. This artificial "red blindness" lasted for some ten minutes, while the "violet blindness" continued for a day or more.

After thus experimenting, Dr. Burch found that it was with difficulty that he could match colours, and if a person made himself partially colour-blind, all colour matches would appear upset.

§ 50. It is rather a curious fact that "colour-blind," or, to be more correct, dichromic vision persons can often distinguish optical differences in colours which appear perfect matches to the normal or trichromic vision. For example, two shades of olive, one dyed with natural dyestuffs and the other dyed with the anilines, may match each other closely, and yet have a different optical structure, and present absorption spectra differing widely from each other. Though such shades appear similar to the normal eye, they will at once be observed by colour-blind people to possess different compositions.

An interesting example is given by Professor Church, F.R.S., where two green solutions were prepared, each appearing identical in hue to the normal colour vision. One solution consisted of neutral nickel chloride and the other acidulated copper chloride. A colour-blind person at once distinguished them as being different stuffs.

It would be rather an interesting fact to know if a person of dichromic vision could detect the small restored fragment restored in the ancient Egyptian sky-blue spherical cup in the Paris Museum, which we have already referred to in § 45, page 76. The author has no doubt whatever but the colour-blind person would at once point out the inserted fragment as showing a different colour, though to the normal colour vision it is of identically the same blue as the cup itself.

CHAPTER VII.

MATCHING OF SILK TRIMMINGS AND LININGS—BEHAVIOUR OF SHADES IN ARTIFICIAL LIGHT—MATCHING OLD FABRICS SOFT SHADES BY MIXING BRIGHT DYES CHANGING OF MIXED SHADES ON EXPOSURE.

§ 51. **The Colour-Matching of Silk Trimmings, Linings, Facings, Bindings, etc.**—In the majority of coloured textiles, such as carpets, table-covers, curtains, calico prints, etc., we pay little heed to their colour appearances under artificial illumination like gas or lamplight.

If, under such conditions, any of the dyed colours show abnormal modifications in hue, we take it for granted that they could not be made to look otherwise. But every dyer and colour-chemist must, some time or other, have experienced the astonishment on viewing certain shades in gaslight, which in good daylight he compared and matched carefully. Many dyed colours are found to match perfectly in good daylight, and yet when viewed in gaslight they are found to be like each other no longer. This is a common occurrence, and, as a rule, the majority of dyers do not give much attention to the aspect of their shades under the artificial lights.

If we make our shades to match what is required in ordinary daylight, then we consider we have accomplished all that can possibly be required of us; and our shades, though altering very greatly in appearance in gaslight, may pass into customers' hands without any complaints being made about them.

But what about our less fortunate fellow colourists, like the dyer of silk trimmings, facings, linings, etc., whose shades *must* be made to appear exactly similar in artificial light to those he is required to match? Here, then, arises a special difficulty in colour-matching, of which the colourist for ordinary textiles happily knows little.

The dyer of silk trimmings and similar goods for ladies' wear generally gets a dyed piece of material, cloth or ribbon, as a specimen shade to which he must match the trimmings and linings to be dyed.

Before a perfect match can be made—perfect as regards the behaviour of the dyed materials under artificial light—the dyer must have some idea of the optical nature and properties of the dyestuffs which were employed in the dyeing of his specimen shade.

Suppose, for example, he gets a piece of dress material of a brownish drab colour dyed with fustin or fustic, an aniline grey like induline with perhaps a touch of methyl-violet, and he wishes to match it on silk trimmings or ribbon by dyeing with an aniline yellow and orange, with the addition of a little wool green or cyanine blue to flatten to the required shade.

By employing these dyestuffs he may be successful in getting a fairly good match in daylight to his specimen shade; but it will be impossible for him to get the two shades to look a match in gas or lamplight. They will present a wide difference in hue, the original piece of cloth appearing somewhat redder, while his shade, dyed to match, will appear of a decidedly *green* cast.

The case might also be the *vice versâ*, as the original shade to match might turn green and the dyer's shade become redder; but, so fastidious is the taste of fashion, that whatever shade the dress article may look like in gaslight—it may change much or change little—the dyer of the silk trimmings and linings must, under all conditions, make his shades to behave in every way similar to the dress stuff.

This, as many of our readers will understand, is no easy task. If the dyer of the dress material were also the dyer of the trimmings, etc., then of course little difficulty would be experienced, as the same colour stuffs employed for the one would do for the other; but as the dyer of the dress fabric is generally a different person from the dyer of the silk trimmings, the latter has to prepare his shades so as to match in every way the dress article.

This involves many difficulties which only the experienced dyer and colourist can appreciate, and though the shades may be matched to the best of the dyer's ability, they may be found faulty when examined in gaslight, and are then complained of as a "horrid" or a "beastly match" by the fair wearers.[1]

§ 52. The reader will find, in the dyed pattern No. 6 (see Appendix) a very good example of this difference in behaviour in apparently similar dyed materials. The piece of silk of the pattern No. 6 was dyed with—

5·0 per cent. naphthol-yellow,
0·5 per cent. acid violet,
0·1 per cent. acid violet 6 BN.

The small piece of woollen dress material attached, which matches the silk closely in daylight, was dyed with—

7¼ oz. orange 4,
5½ oz. indigo substitute.

In ordinary daylight these two pieces of dyed material appear very similar, but if the reader examines them in an artificial light like gas or oil lamp, it will be observed that they present a very wide difference in appearance. The silk turns to a purplish brown colour, while the woollen fabric changes into a strong green olive.

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[1] From a letter received by the author from a skilled dyer of silk trimmings and linings.

And now let us suppose, for example, that a lady has a dress made of the woollen material similar to the small pattern attached at No. 6, in Appendix, and the dress is faced or trimmed with the silk material. In good daylight the dress will appear quite harmonious, and no difference will be observed between the dress and the silk facing. When worn in gaslight, however, the body of the dress would be olive green and the silk facings of a reddish drab colour, which would make a very unpleasant combination. Indeed, a person seeing the dyed specimens at No. 6 for the first time in gaslight could not imagine they would match each other in daylight.

It can be readily understood, therefore, that the subject of colour appearances under artificial illumination is a most important one to the dyers of ladies' cloth materials.

The writer has observed a lady's blue blouse, which was of a beautiful delicate blue in daylight, change into a dull-looking bluish drab in gaslight, while the collar and wristbands—dyed with a different dyestuff—retained their blue in gaslight. For other examples see Chapter VIII., page 92.

Pattern No. 5 in the Appendix, dyed with 5 per cent. Night blue, will be found to be a lovely blue even in gas or candle light.

An excellent practice adopted by many ladies is that of selecting *under an artificial light* the dyed materials which they wish to wear in such lights. By doing so, they will often escape the disappointment of finding that they cannot wear certain dress materials in gaslight.

In such cases as we have cited, where the gaslight aspect of dyed materials is of importance, the writer would strongly recommend the use of an orange-tinted gelatine film. By its use the dyer can see at once the "gaslight" aspect of the shades that are placed before him, and can learn whether they show any decided or abnormal modifications in hue.

For the employment of the orange-tinted film as an aid to dyers and colour-matchers, see § 44, page 75.

It is well to remember that in dyeing soft tertiary shades or "mode hues" by the combination of several dyestuffs, it is advisable always to employ somewhat dull colours for shading purposes If clear bright dyes are employed and mixed with others to form dull shades, the shades so produced are almost certain to prove liable to change greatly in hue under artificial illumination (see § 53). It has already been observed in Chapter V., §§ 37-42, that the optical natures of the dyed fibre and the dyestuff employed exert a powerful influence in modifying the aspect of colours under gaslight.

From my own experience it has been found that *shades which owe their dulness or greyness to the absorption of light, produced by the combination of two or more bright dyestuffs having sharply defined absorption bands in their spectra, always prove more liable to show abnormal changes of hue in gaslight.*

As this subject has now become of considerable importance to every dyer and textile colourist, we have treated it specially in Chapters VIII and IX.

§ 53. **The Colour-Matching of Old Fabrics.**—It sometimes falls to the lot of the colour-chemist to make a perfect match of some fine old piece of carpet, tapestry or print, and he will experience much difficulty in dyeing his shades to match those of the original which have become mellowed and subdued by age and exposure.

As I have said elsewhere,[1] "old coloured fabrics have a quiet beauty of colouring and a harmony of effect which are well-nigh impossible to represent in a new material fresh from the loom.

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[1] *Dyer and Calico Printer*, June, 1899.

"But many manufacturers who do not fully understand the difficulties—we might almost say the exasperating difficulties—of the textile colourist in making a perfect match, fail to see wherein the difficulty lies.

"Put it is quite as reasonable, or shall we say unreasonable, to expect to find in a painting fresh from the artist's brush all the subdued harmony and the rich mellowness of effect seen in a Rembrandt or a Titan, a Raphael or a Domenichino.

"Coloured fabrics, like pictures and other luxuries, require to be 'seasoned' in order to develop that soft mellowness of harmony and effect which the colour-mixer finds it so difficult to imitate.

"No exact rules can be given to assist in the matching of shades subdued by age."

In restoring ancient tapestries in museums, where a new part requires to be pieced to the old, the new piece, after it is coloured, is gently dusted over with French chalk powder or soapstone. This gives a subdued greyness or faded appearance to the new part of the fabric, to make it match well with the old original material

This device, however, is more the nature of a trick, and would not gain favour with textile colour-matchers.

The matching of the colours in old fabrics simply requires more than ordinary care, and a good eye for distinguishing the nicest variations of shade.

Colour-matching, like everything else, requires a considerable amount of patience, experience and skill. The experienced dyer and colour-mixer can tell almost exactly how a certain shade may be obtained; and can even give the relative proportions of the dyestuffs required to produce it.

§ 54. **Matching Shades Produced by the Absorption of Bright Dyes.**—Mention has already been made (see § 52) regarding the difficulty experienced in the matching of the dull soft shades which are composed of several bright and decided colours mixed together. Thus, for example, in producing browns, old golds and olive shades with a mixture of naphthol-yellow, or tartrazine, wool green or patent blues and orange, it will be found that the slightest excess of any one of the constituents at once knocks the colour off its desired shade, and often much difficulty is experienced in dyeing or printing each batch to match exactly the former lots. It is always difficult to match shades accurately when bright and luminous colours are combined to produce the effect. But, if softer and duller colours be employed for mixing purposes, such as azo-carmine, aniline grey or the indulines, indigo blues, patent fustine, etc., the shades produced by admixture are more readily brought up to the desired standard, as a slight excess either of the one or other of the constituents does not produce such a violent effect in altering the hue as with the more luminous dyestuffs.

§ 55. **Changing of Mixed Shades on Exposure to Sunlight.**—If a shade be produced by the combination of two dyestuffs, one a fugitive colour and the other fairly fast, it will, on exposure to sunlight, alter in hue owing to the disappearance of the more fugitive constituent. Thus, for example, a soft shade of mouse brown dyed with naphthol-yellow, methyl-violet and indigo carmine, will change after several months' exposure to the sunlight to a decidedly greener hue. This is owing to the disappearance of the methyl-violet, it being more fugitive than the others. There is thus left in predominance the yellow and the blue, which causes the exposed dyed material to acquire a much greener cast. It must often have been observed that the composite "indigo blues," composed of malachite or China green and methyl-violet, become very much greener, quite blue greens, on exposure to the sunlight. This is owing to the same cause, *i.e.*, the disappearance of the violet constituent. A window curtain dyed olive with tartrazine, orange and an aniline green was found, after long exposure to the sunlight, to have changed into a yellowish old gold colour, owing to the fading of the green constituent, thus leaving the yellow and orange to predominate.

CHAPTER VIII.

ASPECT OF COLOURS UNDER ARTIFICIAL LIGHT—ELECTRIC ARC AND MAGNESIUM LIGHTS—DUFTON-GARDNER LIGHT—WELSBACH — ACETYLENE — ORDINARY YELLOW ILLUMINANTS TESTING MATCHING QUALITIES OF AN ILLUMINANT.

§ 56. **Aspect of Colours in Artificial Light.**—The change in appearance which dyed fabrics undergo when viewed in artificial light is now becoming a question of considerable importance

When any colour composition is viewed under a yellow illuminant like ordinary coal gas or lamplight, the colours undergo a certain change in hue, varying in degree according to the quality of the light and the nature of the absorption spectrum of the dyestuff. If the absorption spectrum be of a normal nature, the colour, when viewed under a yellow illumination like gaslight, will present the *normal* modification aspect; but should the dyestuff possess a peculiar compound spectrum, or any special optical property, then it will present an "abnormal" appearance in gaslight. The following may be described as the normal colour changes observed under a yellow illuminant.

Aspect of Colours of Normal Spectra in Gaslight.

Reds	appear	brighter and like scarlets.
Scarlets	,,	brighter and like oranges.
Oranges	,,	lighter and like yellows.
Yellows	,,	lighter and fade towards white.
Bright Greens	,,	intensified and somewhat yellower.
Blue Greens	,,	like greens.
Blues	,,	duller and trifle redder.
Reddish Blues	,,	redder and like violets.
Navy Blues	,,	like blue blacks.
Violets	,,	redder, like claret reds, deepening to black.
Purples	,,	crimsons.

The above modifications are those generally observed when comparing the daylight with the gaslight aspect of ordinary colours.

If, however, the dyestuff employed in dyeing the fabric should possess any peculiarities either in the structure of its absorption spectrum, or in optical behaviour, then a marked difference from this normal gaslight appearance will be observed.

Two dyed fabrics, for example, may be a very close match in colour during daylight, and yet present a very wide difference in appearance in gas or lamplight, and *vice versa*. Two shades can match each other perfectly in gas or lamplight and yet appear totally off the match when viewed in good daylight.

This is a difficulty with dyers and colour-matchers at the present day, which was not experienced before the introduction of the artificial or aniline dyestuffs.

All the natural dyes, such as indigo, archil, logwood, fustic, bark extract, cochineal, etc., change in the one direction, under an artificial light, *i.e., they all tend to become redder*, but with the aniline dyes, their multiplicity and peculiarity of optical structure give rise to no end of difficulty in colour-matching.

This is specially noticeable in compound tertiary shades, or "broken hues," where the several colour constituents have each their own little peculiarities of optical structure and behaviour. With bright red, orange, yellow and green colours, there is little difficulty experienced in matching in an artificial light, but such shades as drabs, olives, greys, blues, violets, slates, etc., are always liable to change greatly in hue.

There are some blues, such as Night blue, patent blue, cyanine, all of them tending to be greenish in tone, which keep their brilliancy remarkably well in gas or lamplight.

The dyed specimen No. 5, for example, to be found in

Appendix, is a beautiful blue (Night blue), and looks about as well in gas or lamplight as in daylight. This is owing to its absorption of the red end of the spectrum, and its free transmission of the green and blue rays.

The dyed patterns of scarlet, rhodamine pink and orange, to be seen in Nos. 1 to 4, are likewise little altered in appearance in gaslight; but if we examine the other shades, from Nos. 6 to 14, under an artificial light, we will at once observe great changes in their appearance.

With dyed specimen No. 6, for example, in gaslight the silk changes to a *brownish drab* or khaki shade, while the piece of dyed woollen cloth attached to it—though matching the silk in daylight becomes a strong *olive green* shade, showing the widest difference in hue from the silk.

The reason for such strange modifications in hue is found after making a careful spectroscopic examination of the colour itself. Though the two shades are fairly like each other in good daylight, their absorption spectra, as we shall see further on, are very different (see p. 112).

For another example we may take two beautiful azure blues in solution Let one be made by adding a little China or malachite green to a dilute solution of methyl-violet. This gives a fine azure blue in daylight, and it can be readily matched in colour with a solution of Prussian blue, obtained by adding a few drops ferrocyanide of potassium to a very dilute iron nitrate solution. The two blues, when examined side by side in a test-tube in daylight, are identically the same blue colour; but examine them in gas or lamplight, and a wide difference in appearance will be observed. The Prussian blue keeps its beautiful pure blue tone in artificial light, while the composite blue, made with green and violet, changes to a reddish lilac or an amethyst hue. If the solution be strong and deep enough it becomes almost a purple or magenta in lamplight.

This is a simple and characteristic case. By examining the two blue solutions with the pocket spectroscope, such as shown in Fig. 29, page 118, it will be observed that the Prussian blue absorbs the red end of the spectrum and freely transmits the green, blue-green and blue, while the composite aniline blue shows an almost free transmission of the extreme red and orange-red rays. If, therefore, these two colours be viewed in a light containing a large preponderance of red and orange rays—such as gas and lamplight—the colour, which readily transmits or reflects the red and orange, will necessarily appear much redder; while the other, absorbing the red rays, will, to a great extent, preserve an appearance almost similar to its daylight aspect.

The great majority of dyes transmit the red rays, while others transmit the green and blue rays more readily than any of the others; and from this fact arises much of the difficulty experienced in colour-matching, and of the abnormal modifications in hue under artificial illumination.

Suppose, for example, we have a simple carpet pattern done in a series of four fine rich browns, ranging from a deep seal brown, which constitutes the ground colour, to a light old gold shade of its lightest tint. If all the series be made in the same manner, with the same colour constituents, then no want of harmony or balance of the colour scale would be observed when the carpet was viewed in gaslight, or in fact any kind of illuminant. But let us suppose that the colourist dyed his ground shade with orange, fast red and aniline grey or induline, and in the lighter shades of the series he employed wool green, cyanine or patent blues for the saddening agent. The harmony of gradation of the scale may be faultless in daylight, but when the carpet is viewed in artificial light a total want of balance and harmony is at once observed. The lighter figures on the ground become very much greener, and no longer step in harmony with the ground colour which changes little in gaslight. Interesting examples of this are described in § 67 and represented in the coloured frontispiece.

It has been suggested to utilise this different appearance in gaslight of colours apparently similar in daylight by producing woven fabrics having the warp threads dyed by one class of dyes and the woof matching exactly the former, but dyed with colouring matters of different behaviour in gaslight.[1]

In daylight the fabric appears to the eye all of one uniform colour; but when viewed in gaslight a design of a different colour appears on it, produced by the dyed threads changing differently in hue under the artificial illuminant. For example, before me as I write lies a piece of ladies' cloth material showing—under gaslight—a coloured design, *i.e.*, figures of old gold upon a ground of a dull pink or reddish plum colour When viewed in daylight, however, this material is all of one colour, namely, a brownish drab or khaki shade.

Many examples of differences in behaviour in apparently identical colours are constantly met with in the every-day duties of the dyer, and, as we have already seen in §§ 51, 52, give rise to much trouble in colour-matching.

Before proceeding further it may be well to describe briefly the different effects that the various artificial illuminants have on colour appearances.

§ 57. **Electric Arc Light.** - No doubt every textile colourist and colour-matcher must have felt the great need of a good artificial light that can show all colours in their true daylight aspect.

Most of our large dye houses and colour laboratories are fitted up with the electric arc light, which gives a beautifully clear and brilliant light, and forms in most cases an excellent substitute for daylight at night or in the dark winter months.

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[1] See *Manual of Dyeing*, by Dr. Knecht, Rawson and Loewenthal, p. 883.

But every colour-matcher must have experienced that the electric arc, though undoubtedly very good, does not present many of the dyed colours in their true daylight aspect. It has often been found that colour matches made under its light require to be considerably altered when daylight comes This involves serious expense and loss of time.

This is found to occur not only in the dye house but often in paper mills, where a sample of tinted paper requires to be matched while the machine is running at night. What seemed a perfect match in the electric arc light might be found the next morning to be faulty and requiring to be tinted over again.

The ordinary fundamental colours, such as red, orange, yellow, green, blue and violet, may be matched with all safety in the electric arc light; but it is when we come to examine compound shades, such as light drabs, citrines, olives, greys, slates, etc., or the innumerable broken tints, that we find its deficiency.

If we examine under the electric arc the compound dyed shades to be found at Nos 6 to 11 in Appendix, we will observe a considerable difference in their appearance from that of their daylight aspect.

The light obtained from burning magnesium ribbon (see § 58) is even better for matching than the arc light, but even with it some few shades do not appear exactly as in daylight.

A dull greenish *olive* shade dyed with indigo blue, archil and fustic, presents in daylight a wide difference in appearance from a dull *russet* shade, dyed with aniline orange G, naphthol-yellow and wool green. Yet under the electric arc light they appear fairly similar, but with this difference, that the olive shade appears *redder* than the russet a result exactly the opposite from daylight. It is only when the shades are examined "overhand" way, *i.e.*, by transmitted light (see § 35), that their true daylight aspect can be distinguished under the arc light. This fact applies also to the magnesium light (§ 58).

Although most colourists are aware that the electric arc differs slightly from daylight, yet the general opinion is that the arc light is too rich in blue and violet rays. Several writers on the subject have also held the same opinion, and even gone the length of recommending colour-matchers to use *yellowish*-tinted glasses to absorb the slight excess of blue and violet.

But had these writers only tested for themselves the effect of the arc light on the aspect of colours, they would have found that the facts of the case were exactly the opposite.

The present writer pointed out several years ago that glasses of a slightly *bluish* tint were required to give to the electric arc light a truer daylight effect by absorbing the slight excess of the less refrangible red and yellow rays.[1] But if the shades be examined by the "overhand" method as already mentioned, a very good idea of their true daylight aspect is gained

In order to overcome the disadvantages of the arc light to the textile colour-matcher, two investigators, Messrs. Dufton and Gardner, have, after much careful experimenting, introduced a specially tinted copper-blue glass globe for surrounding the electric arc, and thus making its light in exact harmony with good daylight (see further the Dufton-Gardner light for matching, § 59).[2]

We have already observed, in Chapter II., §§ 12-23, that daylight is most variable in its nature, scarcely one hour of the same quality. Such a light has, unfortunately, to be discarded by the scientist in his accurate researches in colour physics, and the steadier and more reliable electric arc light is taken as the standard.

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[1] *Journal Society of Dyers and Colourists*, November, 1896, No. 11, vol. xii., "The Examination of Colours, and their Appearances under the Artificial Illuminants".

[2] *Ibid.*, November, 1900.

§ 58. **The Magnesium Light.**—The brilliant white light produced by burning magnesium wire or ribbon is most useful to colour-matchers who have not the electric light at their disposal. During dull, foggy weather in the winter months, or during night work, the colourist, by burning magnesium, may get a very good idea of the true daylight appearance of shades.

For the purposes of colour examination, in dye houses, paper mills, colour laboratories, etc., various types of magnesium lamps are sold, which, by means of clockwork, can be made to emit its brilliant light for half an hour or more. But to dyers and colour-matchers who are skilled in observing at a glance any differences in shades, such lamps may almost be dispensed with, as a foot of magnesium ribbon held with pincers by an assistant, or even by the colourist himself, answers the purpose equally well.

The aspect of shades under the magnesium light are in the great majority of cases identical to that of daylight. It is only when the shades are of the abnormally sensitive class, such as we have described in §§ 56, 57, *i.e.*, compound drabs, greys, olives, etc., that a slight difference is noticed from their daylight appearance.

To the eye of an observer the magnesium light, like that of the electric arc, appears of a decidedly bluish tinge, but when tested with several of these extra sensitive dyed colours its effect is that of a light having the slightest excess of orange rays in comparison to the daylight.

It is rather an interesting fact that all very brilliant illuminants, such as magnesium light, electric arc, Welsbach incandescent, acetylene gas and oxyhydrogen lime lights, all appear to the eye of a bluish or greenish tinge, and yet they all show in colour-matching an orange or yellowish effect.

Several theories have been propounded to try and explain this, but the true reason still remains doubtful.

To many dyers the magnesium light is of much help in making, what we might term, "snap-shot" examinations of dyed shades during the dark months, or after good daylight has gone.

It has already been mentioned (§ 57) that, with colours very sensitive to change in artificial light, the truest daylight aspect is obtained by viewing them "overhand" method (§ 35).

Investigations made on this subject by the writer show, from the colour-matching point of view, that the magnesium light is slightly superior to the electric arc, but both illuminants prove valuable aids to the colourist.

§ 59. **The Dufton-Gardner Patent Light for Colour-Matching.** This valuable improvement on the arc light, briefly alluded to in a previous paragraph (§ 57), is the result of a long series of experiments by two well-known colourists, Messrs Arthur Dufton, M.A., B.Sc., and Walter M. Gardner, F.C.S., of Bradford Technical College. It consists in surrounding the electric arc light with a specially tinted blue-copper glass globe, which absorbs the exact amount of the preponderating red rays from the arc light, and thus renders it similar to good daylight.

Their first attempts to modify the electric light so as to bring it into exact harmony with daylight were like to end in failure. In an interesting article in one of our dyeing journals,[1] the authors tell us that, after fruitless experiments with a great variety of blue and green colours, they found that the desired effect could be produced by the use of a dilute solution of copper sulphate, which has sharp absorption in the deep red, extending with diminishing intensity into the yellow-green, and great transparency for the blue and violet.

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[1] *Journal Society of Dyers and Colourists*, November, 1900, No. 11, vol. xvi.

Having determined the exact shade of blue required for a certain lamp, they next turned their attention to the production of a blue cupric glass of the same tint. This they found was equally effective, and an electric arc light, surrounded by a globe of the proper tint of blue-copper glass, gives a light of exactly the same character as daylight for colour-matching. The new light has been subjected to the most severe tests, *i.e.*, by examining a series of coloured fabrics dyed with the dyestuffs most liable to change in artificial light, and also by direct comparison with daylight, and in every case the modified electric arc light agreed exactly with daylight.

No other artificial light that we know of can undergo such crucial tests. In every branch of dyeing and colour industry, where shades have to be carefully examined, this Dufton-Gardner light, which may now be obtained in the form of a special lamp,[1] will undoubtedly prove of great assistance.

§ 60. **Welsbach and Acetylene Gaslights.** The other artificial illuminants which come next to the magnesium and electric arc lights in regard to their usefulness for colour-matching are the various forms of the "Welsbach" or incandescent gaslights and the acetylene gaslight. The incandescent lights on the Welsbach principle are a great improvement over the ordinary gas, but though their light presents to the eye a greenish or sickly look, they nevertheless contain a considerable excess of red and yellow rays compared with the electric arc and magnesium lights.

By viewing the shades in the "overhand" way, a much better idea of their daylight aspect may be gained, but this class of illuminants cannot be employed with any degree of safety while matching the sensitive and changeable shades such as we have often had occasion to refer to in the previous pages.

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[1] From Jandus Arc Lamp Electrical Lamp Co., Ltd.

All such illuminants show too great a predominance of the red and orange rays, with a corresponding deficiency in the blue and violet. A simple method of determining the colour-matching qualities of any illuminant is to examine under its light a few crystals of pure sublimed anthracene ($C_{12}H_{14}$). The crystals in daylight possess a beautiful violet or amethyst-coloured fluorescence which is invisible in yellowish or orange-tinted illuminants. From my own experiments there seem only to be three artificial lights capable of showing as in daylight this delicate violet fluorescent colour, and these are the magnesium light, electric arc, and the Dufton-Gardner lights. Under all other illuminants this beautiful violet tinge is lost.

The tabulated results on the next page show the different effects that the three lights, *i.e.*, electric arc, "Welsbach," and acetylene gas, have upon the aspect of dyed shades. It must be noted, however, that most of these shades, *i.e.*, from IV. to VIII., are of the super-sensitive class.

§ 61. **Acetylene Gaslight.** The extreme brilliancy of the flame of this interesting illuminant has naturally suggested the idea that its light might be employed by dyers and colour-mixers for matching their shades when daylight is not obtainable. Indeed, it has often been recommended for colour industries where the finest variations of shade have to be distinguished as a "perfect substitute for daylight," and as "showing colours in their true aspect".

This, however, is a prevalent misconception. The acetylene gaslight possesses many interesting and valuable qualities as an illuminant, but unfortunately this important feature of showing the true daylight aspect of colours cannot be assigned to it. Strange as it may appear, all shades when examined under the acetylene light show the effects of being illuminated with a light having a slight excess of orange rays.

TABLE SHOWING THE EFFECTS OF DIFFERENT ILLUMINANTS UPON THE ASPECT OF DYED SHADES

	Daylight Colours	Composition	Arc Light	Welsbach	Acetylene
I	Olive	Archil, indigo, fustic	Same as day	Not so green	Redder
II	Indigo blue	Patent blue, orange, chromotrop	Same as day	Trifle greener	Much greener
III	Indigo blue	Archil, indigo, naphthol yellow		Trifle redder	Much redder
IV	Old gold	Orange G, naphthol yellow, patent blue	..	Greener	Much greener
V	Moss green	Naphthol yellow, methyl violet	Trifle browner	Redder	More purple
VI	Purple sage (Da[illegible])	Fustic extract, methyl violet 3 B.	Trifle redder	Much purpler	Plum colour
VII	[illegible] green	Acid blue, [illegible]	Same as day	Dull and red	Much redder
VIII	Grey drab	Fast red, [illegible] green	Trifle greener	Greener	Much greener like a sage

From an exhaustive series of experiments it has been shown that the acetylene light, however brilliant and pure it may appear to the eye, cannot be safely employed by dyers and textile colour-matchers.[1]

The delicate violet-coloured fluorescence of anthracene crystals, already alluded to in the previous paragraph as a good test for a suitable matching light, is invisible in acetylene light. Many of the beautiful tints of blue and violet to be found in flowers like the forget-me-not (*myosotis palustris*), the common hair-bell (*campanula rotundi folia*), the hyacinth, the sweet violet, and many others, change greatly in hue in acetylene gaslight. The blues become lavender greys, the lilacs are changed to pinks, and the bluish purples become red violets. Under acetylene light the greenish aniline blues like methylene, turquoise and patent blues turn very much greener in hue, and indeed can scarcely be distinguished from greens. All the many sensitive compound shades, such as olives, drabs, greys, russets, citrines, slates, etc., also change greatly in appearance.

A somewhat amusing instance of the change of appearance under acetylene light may be given from the writer's own experience.

An exact representation of the beautiful skin of the leopard, with its tawny brown colour and its deep maroon spots, was wished to be reproduced upon a carpet. An accurate and careful match of all the colours was made by the dyer, the dull tawny colour being produced with orange, naphthol-yellow and wool green. In daylight the dyed shades were a perfect match to the leopard's skin, and the carpet by daylight was considered quite a success.

But there was considerable astonishment when the carpet was viewed in acetylene light, or in fact in any of the yellower illuminants. The beautiful tawny brown of the leopard was changed into an *olive green*, quite a novel colour for such an animal

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[1] See "The Aspect of Colours under Acetylene Light," by David Paterson, *Dyer and Calico Printer*, March, 1896, also *Journal Society Dyers and Colourists*, 1896, No. 11, vol. xii.

The original skin of the animal showed little change in its appearance in artificial lights.

If the tawny brown colour had been dyed with perhaps some of the vegetable dyestuffs like fustic and archil, or fustine and some of the aniline brown dyes, a shade could have been obtained to keep its right colour like the original even in the artificial light.

Examples such as this prove rather perplexing to the anxious dyer and colour-matcher, but we hope in the following pages to explain the causes which give rise to such differences in behaviour, and thus endeavour to assist him in his difficulties

If the reader wishes a more exhaustive account of the behaviour of different colours under the acetylene light, he may consult the two articles already mentioned in the footnote of previous page.

§ 62 The ordinary illuminants like *coal gas*, *oil lamp*, *electric glow lamp* and *candle light* are all too rich in red and orange rays to be of any service as a substitute for daylight in colour-matching.

They are nevertheless of value to the colourist, as by viewing shades in such a light he can often discern peculiarities of hue and optical behaviour that would otherwise totally escape his detection in daylight.

Thus, gas or lamplight may be employed with advantage in examining the blue, violet and green class of colours, and also many compound shades, as slight differences in hue or in optical structure, which might be overlooked while matching in white daylight, become so accentuated under an orange illuminant as to be at once apparent.

For example, two blues may match each other closely, but one may have the very slightest tendency to be more of a violet hue; under gaslight their difference becomes at once visible. The latter shade is turned much redder.

Many similar examples might be given with greens, blue-greens and violets.

Every colourist knows the usual changes in appearance which ordinary colours undergo in gas or lamplight.

We have already described most of these modifications in § 56. Red and orange appear brightened, yellow seems to fade, and light tints of yellow appear white, so that pale yellow and white are indistinguishable in a yellow or orange illuminant. The primrose and the white lily both appear the same tint, and pale yellow gloves cannot be distinguished from white ones. The beautiful class of pinks, such as the eosines and rhodamines, which owe that characteristic beauty to their bluish bloom, lose much of their blueness in gaslight and tend to appear more orange.

Greens, blues and violets, with all their intermediate hues, become more modified the nearer they approach to the violet end of the spectrum. This is owing to the great deficiency of the blue and violet rays in all the common illuminants.

Coal gaslight in comparison with daylight contains only about 20 per cent. of the green rays, 10 per cent of blue, and 5 per cent of the violet rays. All colours, therefore, belonging to the blue and violet class must accordingly become altered in appearance under such a light.

There are some beautiful aniline blues, however, such as Victoria blue and Night blue (a dyed specimen of which will be seen as No. 5 in the Appendix), methylene and Nile blues, which will keep their clear blue colour remarkably well even in gaslight. This is owing to their absorption of the red rays, and the free transmission of all the green, blue and violet ones. Consequently, such blues, even when illuminated with an artificial light, preserve to a great extent their beauty of hue.

It will always be found the case when the coloured rays reflected by any colour are confined to one certain portion of the spectrum, either red, yellow-green or blue, that such colours do not show a great modification of hue under any of the ordinary artificial lights. If the blues contain a quantity of red in their composition, then they are certain to change in hue in gaslight.

A splendid bright green, which keeps its colour beautifully in any ordinary illuminant, may be dyed with three parts quinoline yellow and two parts acid green. Such a green dyed on silk is as bright and lustrous in gaslight as it is in daylight. By studying its absorption spectrum we find that it transmits, as nearly as possible, only the pure green rays about the lines E of the spectrum. Such a colour will keep its hue even in gas or candle light. In dyed pattern No. 6, in the Appendix, we find two colours very similar in daylight and differing widely in gaslight. The silk pattern shows a free transmission of the red rays, while the woollen material attached shows strong absorption in the red and free transmission of the green and blue rays. In daylight the optical properties of the two are about equally balanced, making what we term a "match." But, whenever these colours are examined under a light possessing a predominance of red and orange rays, then the equilibrium of hue is disturbed, the dyed silk is ready to transmit any amount of red rays; while the woollen material absorbs the red, and transmits more readily the green rays: consequently they appear in gaslight widely different in hue. The silk becomes a dull reddish brown, while the woollen material becomes a strong olive green. This is seen at once by viewing them in gas or lamplight.

Other examples, but less pronounced, may be found in the dyed pattern plates, Nos. 7 to 14, which are fully described in Chapter IX., pages 111-119.

We have already observed that the *compound shades* are very liable to show abnormal changes of hue in gaslight. Their "gaslight aspect" depends upon *the most changeable colour constituent in their composition.*

For example a slate blue dyed with azo-yellow, fast acid blue and cyanine blue, *reddens* considerably in gaslight, even though it contains cyanine blue, which turns much greener in gaslight. But the greening power of the cyanine blue—if we might so express it—is over-ruled or masked by the more sensitive fast acid blue, which *reddens* in gaslight, so that the resultant aspect is produced by the latter more changeable dyestuff. In a similar manner olives made with orange, yellow and wool green turn much greener in artificial light; but if a proportion of the wool-green constituent be replaced by methyl-violet 3 B, a similar daylight shade of olive is produced, which, however, becomes *redder* instead of greener in gaslight. This is owing to the greater changeability of methyl-violet than the cyanine blue in gaslight

One of the worst illuminants by which to judge colours is the electric *glow lamp*, as it contains such an excessive predominance of the red and orange rays. Even the most experienced colourist may be completely deceived as to the true aspect of the shades examined under it. It is a wise plan, which many ladies adopt, to select by gaslight or the electric glow lamps of the shops those dress materials and colours which are intended only for evening wear.

Many a person might thus be saved the disappointment of finding that some beautiful soft shades selected in the daylight become crude and disappointing in the gaslight, and likewise the converse.

A somewhat amusing instance occurred to the writer himself, and even at the very time he was specially engaged in the study of colour appearances under artificial lights. Going to stay with a friend, he wished before doing so to purchase a silk neck-tie, and selected, under the light of the electric glow lamp in the shop, one which seemed to him of a remarkably chaste and refined pattern. It was of a beautiful soft dove-grey with a white stripe. Imagine his surprise and humiliation next morning when it turned out to be a garish *peacock blue with a yellow stripe*.

Under the strongly orange-tinted illuminant, yellow could not be distinguished from white, and such a light being so greatly deficient in the blue and violet rays, caused this certain blue to be so saddened as to appear a soft grey.

§ 63 **Testing the Matching Qualities of an Illuminant.** In order to test an illuminant for its colour-matching qualities, it is necessary to examine under its light a selection of coloured materials which show abnormal colour changes under gaslight. The delicate tints of blue and violet to be found in many varieties of common flowers, such as the hare-bell, hyacinth, forget-me-not, sweet violet, the delphiniums, etc., are very sensitive to any artificial illumination, and form useful *test-colours*. The delicate violet-coloured fluorescence of anthracene crystals has already been referred to (see § 60) as a simple and delicate test for showing if an illuminant is of good colour-matching quality.

But perhaps the most practical *test colours* are those delicate compound dyed shades produced with many of the aniline dyes. It is possible, by selecting certain classes of dyestuffs and combining them, to produce very sensitive shades, which change their aspect with even the faintest difference in the quality of daylight. Some of these shades alter in appearance with the time of the day, and what was considered a match in the morning is off the desired match in the afternoon. We have already mentioned compound shades of this nature (see §§ 51, 52), and the dyed specimens to be found in the Appendix, especially No. 6, and the pairs from 7 to 14, show interesting changes. It must be remembered, however, that in order to judge correctly the modifications which the dyed shades undergo in gaslight, we must have for comparison other shades, similar in daylight, which show little or no change of hue under such conditions. The differences in behaviour are then more accurately noted than if we depended solely upon the *memory* of their daylight aspect. It is well to remember, as we have already observed in the cases of the acetylene and Welsbach lights (§§ 60, 61), that the brilliancy and apparent whiteness of the illuminant to the eye cannot be taken as a guide to its colour-matching qualities.

CHAPTER IX.

INFLUENCE OF THE ABSORPTION SPECTRUM IN THE CHANGES OF HUE UNDER ARTIFICIAL ILLUMINATION—ABSORPTION SPECTRA OF TWO SAGES—TWO SLATE BLUES—TWO GREY DRABS—STUDY OF THEIR DIFFERENT BEHAVIOUR AND OPTICAL PROPERTIES—ABNORMAL MODIFICATIONS UNDER GASLIGHT

§ 64. In the preceding chapters we have repeatedly referred to the abnormal changes in the appearance of many dyed shades when examined under artificial illumination, and we have also observed that this phenomenon is due to a peculiarity in the nature of the absorption spectra of the dyestuffs themselves.[1] As this interesting subject is becoming every year of greater importance to all textile colourists, we intend now to devote to it a little special attention.

Two shades of a dull green sage can be obtained by dyeing in the first instance with methyl-violet and naphthol-yellow, and in the second instance, with naphthol-yellow, wool green S., and a trace of red or scarlet. The two shades so made may match each other accurately in daylight, but under gaslight, or any ordinary artificial illumination, they present a wide difference in appearance. The first shade dyed with violet and yellow becomes a *reddish-brown* in gaslight, while the other shade becomes an *olive*.

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[1] The writer has shown that dichroism and fluorescence possessed by the dyes, and also the optical properties of the fibre itself, affect, in a slight degree, the "gaslight aspect" of dyed colours.—(See *Journal Society Dyers and Colourists*, November, 1896.)

In order to explain the strange difference in the behaviour of two apparently similarly dyed materials, let us examine the colours with the spectroscope.

No. 2 of Fig. 27 represents the appearance of the absorption spectrum of the sage dyed with naphthol-yellow and methyl-violet. No. 1 is the solar spectrum with all the hues in their normal intensity.

It will be observed that the shading in the diagram represents the absence or absorption of the coloured rays of the spectrum at that certain part. This absorption spectrum of No. 2 shows the sage colour to consist of the red and a portion of the green part of the spectrum, while the orange and yellow at the D line, and the blue and violet from F to H lines, are all quenched or absorbed.

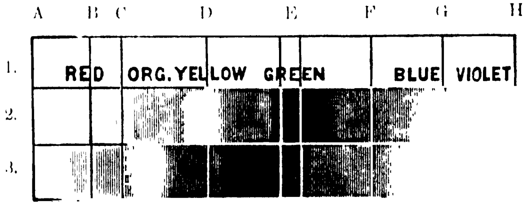

FIG. 27.—Showing the optical difference in structure of two shades of sage identical to the eye. No. 1 is solar spectrum. No. 2, absorption spectrum of sage produced with methyl-violet and yellow. No. 3, absorption spectrum of sage produced with yellow, wool green and small quantity of red.

The strong absorption band at the yellow is caused by the methyl-violet constituent, while the absorption of the violet and blue rays is caused by the naphthol-yellow.

By looking at this absorption spectrum, it will be at once observed that the red from A to C lines is freely transmitted; while there is a decided tendency to absorption in the yellow-green and blue-green parts of the spectrum.

If now we view such a shade as this in a light which is deficient in the green and abundant in the red rays, like any of the ordinary illuminants, it will be readily seen that the shade presents a very much *redder* appearance, owing to its free transmission of the predominating red rays and its tendency to absorption of the deficient green rays.

Diagram 3, Fig. 27, represents the absorption spectrum of the other sage colour, exactly matching in daylight No. 2, but dyed with naphthol-yellow, wool green S and a small quantity of red. It will be at once observed that it differs from No. 2 above it. In No. 3 there is strong absorption in the cherry-red between the C and D lines, caused by the wool green, and there is more or less a tendency to absorb a certain portion of the red rays. This is shown by the faint shading of the red, B to C in the diagram. The yellow-green and a considerable portion of the green rays are freely transmitted. This, it will be observed, differs greatly from the spectrum of No. 2.

Then follows the gradual absorption of the blue and violet similar to that of No. 2 spectrum.

By comparing in this manner these two spectra of shades, apparently identical to the unassisted eye, the spectroscope has thus revealed the cause of the differences in their behaviour under gaslight.[1] Shade No. 3 shows a tendency to absorb the red rays at the B line, and a strong absorption of the cherry-red where the shade No. 2 shows free transmission of those rays.

Then spectrum No. 3 shows free transmission of the yellow-green where No. 2 shows strong absorption.

Thus, No. 3 shade, dyed with wool green, yellow and a little red, when viewed under an artificial light, will show a freer transmission of the yellow-green and green than No. 2; hence its gaslight aspect must be *greener.*

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[1] It is unnecessary here to enter upon the principles underlying colour absorption and of the theory of the spectroscope, readers are referred to Chapters III. and IV. of companion volume, *The Science of Colour-Mixing.*

By viewing the dyed pattern No. 6 in the Appendix, we may see a very good example of an exactly similar case. The silk pattern has been dyed with—

5·0 per cent. naphthol-yellow,
0·5 per cent. acid violet,
0·1 per cent. acid violet 6 BN.

The absorption spectrum is exactly similar in nature to that of No. 2 in Fig. 27 we have just described. The small piece of dyed woollen material attached to the silk matches fairly well with the silk, and was dyed with—

0·5 per cent. orange 4,
0·35 per cent. indigo substitute.

Its absorption spectrum closely resembles that of No. 3. If the two dyed fabrics be examined in gaslight, the widest difference in hue is observed, corresponding to that just described and explained.

The silk material having a spectrum like No. 2, Fig. 27, changes to a dull reddish-brown shade, while the dyed woollen material, having a spectrum resembling No. 3, becomes a strong olive green.

In the case of the dyed silk the modifying constituents are the acid violets, especially *acid violet* 6 BN, which reddens much in gaslight, and in the other instance it is the indigo substitute which becomes *greener*, and the orange disappears under similar conditions.

On examining the spectra of these sage colours shown in Fig. 27, it will be observed that they consist principally of red and green rays, greatly toned down or "saddened" by absorption of all the other rays of the spectrum. When we remember that a mixture of red and green-coloured lights produce the sensation of *yellow*, we at once see that this sage colour consists practically of a much degraded or saddened yellow, *i.e.*, a yellow mixed with a large proportion of grey. Then if this be so, we should be able to match such a sage colour by simply dulling yellow with a certain proportion of grey

And this is so. A colour matching the two sages already described may be dyed simply with a yellow and an aniline grey, thus producing a shade of greenish sage

It is needless to say that a shade thus produced does not show any abnormal changes of hue in gaslight where a more complex shade would It has no peculiarity in its absorption spectrum, being merely a saddened or "broken" yellow

A similar example to these sage colours will be seen at dyed specimens Nos 13 and 14 which will be described as we proceed

§ 65. The dyed patterns Nos 7 and 8 (see Appendix) are two shades of deep slatey blue which appear fairly like each other in daylight, but in gaslight they present a wide difference in hue.

Dyed pattern No. 7 appears much greener in shade, while No 8 is a very deep purply slate grey in gaslight

If we study the absorption spectra of these two dyed colours, we find that No 7 shows a strong absorption in the red part of the spectrum lines B to C, while in shade No 8 the red portion is largely transmitted The absorption spectra of these tertiary shades, containing three or more different dye constituents, are often of a very complicated nature and difficult to analyse with the spectroscope The little luminosity they possess, being merely greys with a predominating hue, greatly increases the difficulty. I have endeavoured, however, to represent the absorption spectra of these two shades in the annexed Fig 28

Spectrum A represents the absorption curve of dyed shade No. 7, while A′ represents the shaded spectrum corresponding in absorption to the curve above it.

This shade was dyed with—

1 kilo. patent blue,
80 grammes orange G,
20 ,, chromotrop 2 R.

The strong absorption in the red is due to the patent blue constituent, while that in the yellow, green, blue and violet is owing respectively to the chromotrop and orange dyes.

It will be observed from this absorption diagram that the green at the E lines is more freely transmitted than the red.

Spectrum B, Fig 28, represents the absorption curve of the dyed shade, No. 8, and B′ the shaded spectrum, corresponding in absorption to the curve below it. The two spectra A′ and B′ are brought close together in the diagram for the sake of easier comparison.

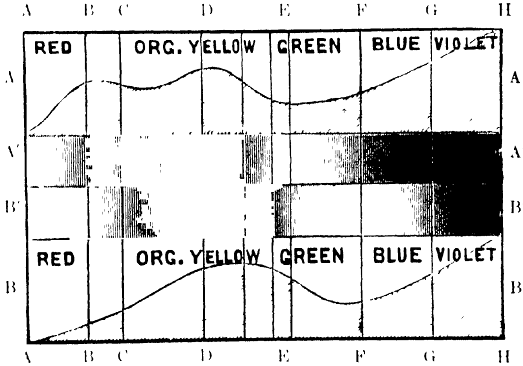


FIG. 28. Showing absorption spectra of two similar shades of deep slate blue. A, A′, dyed with patent blue, orange and chromotrop. B, B′, dyed with orchil, indigo and naphthol yellow. Both shades similar in daylight, but widely different in gaslight.

This shade was dyed with—

4 kilos orchil,
2½ ,, indigo carmine,
2 grammes naphthol-yellow S,

and it will be observed that it differs in construction from that of A′. The red is transmitted, while the green at E lines is strongly absorbed, due to the orchil constituent, and the blue-green and blue are transmitted.

These two diagrams, A A′ and B B′, Fig. 28, may be taken to represent the absorption spectra of the two dyed patterns Nos. 7 and 8, and from their study we can now understand the different behaviour of the two dyed materials under artificial illumination.

Shade A, dyed with patent blue, orange and chromotrop, shows greater readiness to transmit the green than any other part of the spectrum, and shows likewise absorption in all the red part of the spectrum. Such a shade, under an artificial light, becomes very much greener. For example, if we examine under gaslight the dyed pattern shade No. 7, we will see how the green predominates.

Shade B, Fig. 28, dyed with orchil, indigo carmine and naphthol-yellow, shows a free transmission of most of the red rays and strong absorption of the green at the E lines, owing to the orchil constituent. We can see from this that indigo, though a blue dyestuff, freely transmits the red rays as well. The absorption of the violet, blue-violet and blue is due to the naphthol-yellow constituent.

This shade when viewed under gaslight must become very much redder, as we can see from its spectrum B and B′ that the red rays are readily transmitted. It is owing to this fact, therefore, that the dyed slatey blue shade, No. 8 in Appendix, becomes much redder in hue in gaslight. In the spectroscopic examination of dyestuffs the small direct vision instrument shown in Fig. 29 will be found most useful. It can be carried in the waistcoat pocket.

§ 66. In dyed patterns Nos. 9 and 10 we have a very similar example. Both shades match each other and are of a dark plum drab in daylight, but in gaslight No. 9 appears a very dark sage grey, while No. 10 is a deep shade of plum, approaching a maroon. On analysing their construction, we find them to show the same properties as the two shades just described in Nos 7 and 8, and this might be expected, seeing that they are dyed with similar groups of dyestuffs.

No. 9 was dyed with

180 grammes patent blue,
300 ,, orange,
355 ,, chromotrop,

while No 10 matching it was dyed with --

6 kilos orchil,
2½ ,, indigo carmine,
50 grammes naphthol yellow

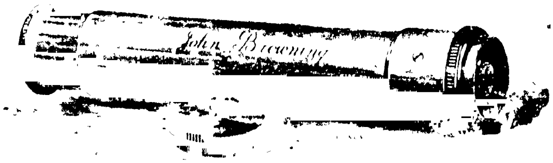


Fig. 29 Direct Vision Spectroscope

The patent blue constituent of No 9 gives it the property of greening much under an artificial light, owing to the free transmission of the green and the absorption of the red rays possessed by this dyestuff.

On the other hand, the natural dyestuff, orchil, in No 10, possesses properties of an exactly opposite nature, being strong in absorption of the green and free in transmission of all the red rays The indigo or blue constituent of No 10 also shows transmission of the red. We can readily understand, therefore, how two shades apparently similar in daylight to the unaided eye, but compounded of dyestuffs of different optical natures, are bound to behave differently under the yellow artificial illuminants.

The dyed specimens of subdued plum colour, Nos. 11 and 12, resemble each other fairly well in daylight and yet present a wide difference under gaslight—No. 11 appearing much flatter and more of a brown, while No. 12 becomes much redder, approaching a claret. The reason for this may now readily be understood from what has been said previously.

Shade No. 11 was dyed with—

220	grammes	patent blue,
220	,,	orange G pat.,
560	,,	chromotrop 2 R pat.

Under yellow artificial lights the orange disappears to a great extent and the patent blue becomes much intensified. The result is that the gaslight aspect of the colour is very much flatter or bluer, making it of a dull brown or russet colour.

With dyed specimen No. 12 the opposite effect is produced.

It was dyed with—

12	kilos	orchil carmine,
1	,,	indigo carmine,
50	grammes	naphthol yellow S.

As we have already observed, yellow disappears in a yellowish illuminant, while the natural dyestuffs orchil and indigo, allow a ready transmission of all red rays. It follows that such a colour as shade No. 12 will naturally become very much redder in gaslight than its corresponding shade No. 11. A very striking difference in behaviour between two apparently similar dyed materials is found also in the two last dyed specimens, Nos. 13 and 14.

Pattern No. 13 was dyed with—

200	grammes	patent blue,
300	,,	orange G pat.,
80	,,	chromotrop 2 R pat.

The large excess of orange present in the dyed material as seen in daylight disappears greatly in gaslight, with the result that the shade instead of its being a soft fawn or khaki colour becomes a dull *sage green* under gaslight. The decrease of the orange, combined with the increase of the patent blue, produces this result. Pattern No. 14, which closely resembles No. 13 in daylight, becomes a *reddish drab* in gaslight.

It was dyed with—

3 kilos. orchil carmine,
1 ,, indigo carmine,
1½ ,, naphthol-yellow S.

From what has already been stated, one can at once predict how a colour of this composition will behave in gaslight. The indigo blue tends to redden in gaslight, in direct contrast to the patent blue, which becomes much *greener*; the orchil reddens greatly, while the yellow inclines to disappear. The results are that No. 13 becomes much *greener*, and No. 14 becomes much *redder* in gaslight than in daylight.

§ 67 The coloured plate (see frontispiece) represents some abnormal changes in hue of dyed fabrics. Fig. 1 shows a pattern done in two shades of olive, the dark ground shade dyed with naphthol-yellow, wool blue and methyl-violet, while the light shade of yellowish olive is dyed with yellow, orange and wool green, or patent blue N. In daylight the two olives appear of the same class and quite in harmony, but under gaslight their change of hue is very great, representing something like Fig. 2. The dark olive containing methyl-violet as a constituent reddens into a russet shade, while the light olive turns very much greener owing to the wool green or the patent blue constituent. The daylight appearance of the fabric, therefore, is widely different from that of gaslight, and may be represented somewhat like Figs. 1 and 2 of frontispiece.

Figs. 3 and 4 (frontispiece) represent the same phenomenon in a more curious aspect. The lightest shade of terra-cotta has not been made with the same dyestuff as the ground and the second shade. Though harmonising well enough in step in daylight with the general tone of the two other shades, in gaslight it goes quite off the cast (see Fig. 4), and becomes so green as to appear a distinctly different colour.

The ground and second shades were dyed with orange, azo acid magenta and indigo substitute BS, but the light tint had, in place of the indigo, the dyestuff wool green S. The harmony of colour gradation or "step" of the composition was faultless in daylight, as shown in Fig 3, and all the shades appeared of the same nature and composition; but under artificial light the lightest tint at once stood out from the other colours as being of a different greener cast (see Fig. 4)

Of course it must be remembered that the examples we have chosen are somewhat exaggerated, and could scarcely be produced in actual practice unless through some gross carelessness of the dyer, or with the studied view of obtaining such curious results. Nevertheless it requires the utmost care in the selection of the dyestuffs to obtain a colour which behaves in all respects similar to the shade it is desired to match.

§ 68. **Unreliable Dyestuffs.**—While speaking of the difficulties of colour-matching, we cannot but refer to a very important question, *i.e.*, the varying and unreliable quality of some of the dyestuffs used.

As a rule, dyers and colour-mixers prefer to keep closely to their standard dyes, which they have found after long experience to be regular in strength and quality. They are naturally very slow—and rightly so—to adopt a new brand of dyestuff, even though it promises well in their trial experiments, because they have, no doubt, learned from bitter experience that many dyestuffs after being adopted prove to be uncertain in strength and quality of tone

After colour recipes have been altered and adjusted to suit the new dyestuff, it may be found, on examining the next delivery of the stuff, to be slightly different in quality. This upsets completely the colour recipes, and gives the dyer no end of trouble in matching his shades to the required standards. This is one of the most annoying experiences of the colourist. Month by month the dyestuff may creep almost imperceptibly off the correct tone unless the utmost vigilance be exercised.

It is very important that every colourist should keep a small sample of the dyestuffs as bargained for while making the contracts for the year, so that they may be kept for comparing with the future deliveries of the dyestuff.

But in the best regulated colour laboratories, and although the utmost care be exercised, it may be found that the dyed shades are not coming out just as they are desired. They may require to be altered and adjusted with one dyestuff or another to bring them to the correct shade, and it is here that the colour-matcher experiences most difficulty.

It is hard for any person not skilled in the practical mixing and matching of colours to believe that a dyestuff giving tones of colour almost identical to its required standard may, when mixed with other dyes to form compound shades, produce results very different from what were expected.

Yet, as every colourist knows, this may be so. For example, two shades of brown may appear identical, yet when each is mixed with a certain proportion of green or blue the two shades of terra-cotta thus produced may not be at all similar.

In the same manner two aniline greys or indulines may appear, when dyed by themselves, of exactly the same colour, yet if there be added a certain proportion of pink to form a soft purple, or a yellow to give a citrine, or an orange to give a russet, the resulting pairs of shades may differ considerably.

Some slight difference in hue, between the two greys, not observable at first, becomes apparent on its admixture with other colours.

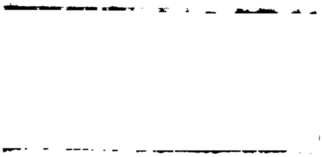
Here, then, arises a great source of difficulty to the colour-matcher; and it requires the colour manufacturers and their agents to thoroughly appreciate the importance of this subject, and to exercise the utmost care that all deliveries of dyestuffs are unvarying in strength and tone of colour.

At the present day, when business runs at high speed and everything is bustle and hurry, the colourist has no time to waste on altering shades and adjusting his recipes to suit a vacillating and uncertain dyestuff, no matter how anxious he might be to use it.

This subject is a most important one to dye manufacturers, and well worthy of their closest attention.

DYED SPECIMENS ILLUSTRATING TEXT, PLATE I.

(WEIGHTS ARE FOR 100 LB. WOOL.)

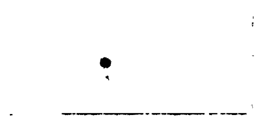


Dyed with
[illegible] per cent Orange [illegible]
[illegible] Acid
Magenta

o 2

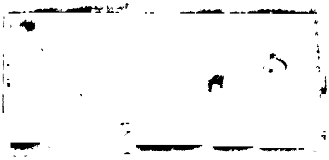
Dyed with
2 per cent Rhodamine

o 3



Dyed with
2½ per cent Palatine
Scarlet

o. 4



Dyed with
2½ per cent Orange
No. 2.

DYED SPECIMENS ILLUSTRATING TEXT, PLATE III

(WEIGHTS ARE FOR 100 LB. WOOL.)

No. 9.

Dyed with
480 grs. Patent Blue,
300 grs. Orange G.,
355 grs. Chromotrop 2R.

No. 10.

Dyed with
6 kilos Orchil Carmine,
2½ kilos Indigo Carmine,
50 grs. Naphthol Yellow.

No. 11.

Dyed with
220 grs. Patent Blue,
220 grs. Orange G.,
560 grs. Chromotrop 2R.

No. 12.

Dyed with
1½ kilos Orchil Carmine,
1 kilo Indigo Carmine,
50 grs. Naphthol Yellow.

DYED SPECIMENS ILLUSTRATING TEXT, PLATE IV

(WEIGHTS ARE FOR 100 LB. WOOL.)

No. 13.

Dyed with
1200 grs. Patent Blue
300 grs. Orange G
80 grs. Chromotrop R

No. 14.

Dyed with
3 kilos Orchil Carmine,
1 kilo Indigo Carmine,
1½ kilos Naphthol Yellow

For these beautiful dyed patterns illustrating our text we are indebted to two eminent colour firms: Messrs. The Badische, Ludwigshafen, a/m Rhine, for Patterns No. 2, 3, 5 and 6 (silk), and to Meister Lucius & Bruning, Hoechst, a/m Maine, for Patterns No. 1, 4, 6 (wool) and 7 to 14.

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